UNCLASSIFIED

AD NUMBER AD282886 LIMITATION CHANGES TO: Approved for public release; distribution is unlimited. FROM: Distribution authorized to DoD only; Administrative/Operational Use; 04 JAN 1962. Other requests shall be referred to Dept. of the Army, Springfield Armory, MA. AUTHORITY SA per DTIC form 55

UNCLASSIFIED

AD 282 886 L

Reproduced by the

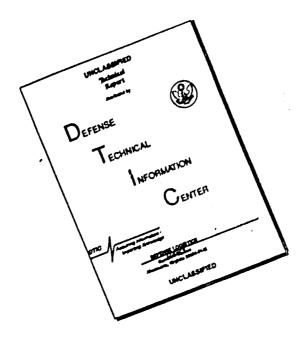
ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.



SPRINGFIELD **ARMORY**

ALOGED BY A

SPRINGFIELD, MASSACHUSETTS RESEARCH AND DEVELOPMENT

> Report: SA~TR19-1507

4 January 1962 Date:

Report Title:

Properties and Methods of Nondestructive Testing

of Bolts for 7.62mm M14 Rifles

Authors

Physicist

Approved

H. F. HAWTHORNE

Chief, Res and Dow Div

Physicist

Industrial Production Engineering project

Supv Phy Metallurgist

OMS Code:

4010.25.0005.2.01

The Code Sheet will be removed from the report when the report is loaned or otherwise distributed outside the Department of Defense

NOX

ORDED Form 722 7 Apr 60



CODE SHEET INCLUDED.

ASTIA AVAILABILITY NOTICE. U. S. Military agencies may obtain copies of this report directly from ASTIA. Other qualified ASTIA users should request through Commanding Officer, Springfield Armory, Springfield, Mass. ATTN: ORDBD-TX.

The findings in this report are not to be construed as an official Department of the Army position.

SA-TR19-1507 Report:

Date: 4 January 1962

Report Title: Properties and Methods of Nondestructive Testing of Bolts for 7.62mm M14 Rifles

Authors

R. D. KORYTOSKI

Physicist

Approved

H. F. HAWTHORNE

Chief, Res and Dev Div

Physicist

Supv Phy Metallurgist

Industrial Production Engineering project

OMS Code: 4010.25.0005.2.01

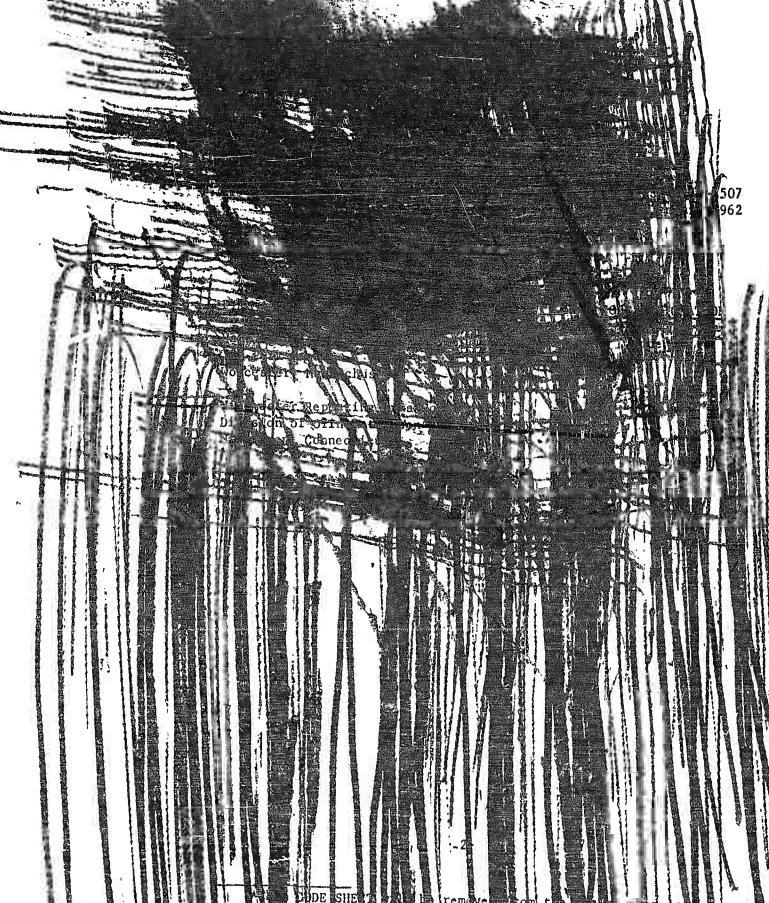
The CODE SHEET will be removed from this report when the report is loaned or otherwise distributed outside the Department of Defense.

RESTRICTION ON REDISTRIBUTION. The distribution of this report is restricted. [nitial distribution has been made in accordance with the attached distribution list. The addressees thereon shall not make any redistribution.

LIMITATION OF REPRODUCTION. Reproduction of this document, in whole or in part, is prohibited except with permission of the originating office.

DISPOSITION. Destroy. Do not return.

10.



TOTAL AND SHE TOTAL TOTA

The state of the s

ï

À

ABSTRACT

Studies were made to develop adequate inspection methods of evaluating properties of material used in the fabrication of the 7.62mm M14 bolts, and to determine the feasibility of using the developed method for final and in-process inspection. These studies included (1) investigation of bolt malfunction, (2) nondestructive tests re magnetic permeability comparisons, measurements of basic magnetic properties, oscilloscope wave form pattern studies, hardness investigations, (3) bolt segregation tests, (4) simulated impact tests, and (5) application to final and in-process inspection. A test method combining Rockwell C surface hardness, magnetic permeability readings, and oscilloscope wave form patterns was developed to evaluate properties of material asad in the 7.62mm M14 bolt. The combination test method was found to be too complicated to specify as a final or in-process inspection method. A magnetic comparison method similar to that employed in the segregation program could be used as a means to determine uniformity of components within individual heat lots. Procedures are discussed and results given. It was recommended that the investigative program be continued.

CONTENTS

	Page
Title	1
Code Identification	2
Abstract	3
Contents	4
List of Tables and Illustrations	5
Subject	6
Purpose	6
Scope	6
Conclusions	6
Recommendations	7
Introduction	8
Investigations, Bolt Malfunctions at Ft. Benning and at "Code HG" Plant	9
Investigations, Nondestructive Magnetic Test: Studies	18
Final and In-Process Inspection	38
Appendix A - Graphs	40
Appendis B - Distribution	67

REPORT SA-TR19-1507

	TABLES AND ILLUSTRATIONS	Page
Figure 1.	Fractured Bolt Head, Rifle, 7.62mm, M14 "Code WR", No. 19453	10
Figure 2.	Damaged Bolt Face, Rifle, 7.62mm, M14 "Code WH", No. 19453	11
Figure 3.	Fractured Bolt_Showing Fracture Surface of Broken Right Locking Lug, Rifle, 7.62mm, M14 - "Gode WH", No. 19453	12
Figure 4.	Photomicrographs Displaying Case and Core Microstructures of Fractured "Code WH" M14 Bolt - Rifle 19453	15
Figure 5.	Photomicrographs Displaying Case and Core Microstructures of Springfield Armory M14 Bolt - Rifle 19656	16
Figure 6.	Photomicrographs Displaying Crack, Case and Core Microstructures of "Code HG" M14 Bolt - Rifle 73293	17
Figure 7.	Test Specimen for Case Depth, Free Ferrite and Core Hardness Tests	19
Figure 8.	Magnetic Analysis Production Comparator Test Equipment	20
Figure 9.	Arrangement for Retentivity Measurement	22
Figure 10.	Opposing Current Versus Core Hardness on "Code WHY Bolts	23
Figure 11.	Experimental Arrangement for A.C. Hysteresis Loop Messurement	8 25
Figure 12.	Plot of Coercive Force Versus Magnetic Comparator Readings	28
Figure 13.	Chart Relating Surface Hardness, Magnetic Reading, and Core Hardness	31
Figure 14.	Wave Form Patterns Correlated with Material Properties	34
Figure 15.	Wave Form Patterns of Highly Tempered or Retempered Bolts	37
Table 1.	Coercive Force, Residual Flux Density, and Core Hardness Data on "Code WH" Bolts	26
Table 2.	Hysteresis Loop and Hardness Data on Bolts Normally Tempere and Retempered at High Temperatures	d 27
Table 3.	Effect of Surface Hardness on Magnetic Readings	29
Table 4.	Effect of Core Hardness on Magnetic Readings	30
Table 5.	Data on Bolts with Basic Wave Form Patterns	32

SUBJECT

Nondestructive Test Investigation of 7.62mm M14 Bolts.

PURPOSE

This investigation was conducted to develop adequate inspection methods for evaluation of material properties of bolts impounded because of serious weapon malfunctions, and to determine the feasibility of the developed method for final and in-process inspection of bolts to control quality.

SCOPE

A summary of the following investigations conducted by Research and Materials Laboratories, Springfield Armory, is given.

- 1. Investigations of Bolt Malfunction at Fort Benning and at "Code HG" Plant.
- 2. Nondestructive Test Studies.
 - a. Magnetic Permeability Comparisons
 - b. Measurements of Basic Hayneric Properties
 - c. Oscilloscope Wave Form Pattern Studies
 - d. Hardness Investigations
- 3. Bolt Segregation Tests.
- 4. Simulated Impact Tests.
- 5. Application to Final and In-Process Inspection.

CORCLUSIONS

- 1. A test method combining Rockwell C surface hardness, magnetic permeability readings and oscilloscope wave form patterns was developed to evaluate material properties of boits impounded at Raritan Arsenal. A total of 33,808 bolts was inspected, with 26,848 of these reassembled into weapons.
- 2. The combination test method is too complicated to specify as a final or in-process inspection method. Engineers experienced with the segregation program and cognizant of wave pattern
 differences and resultant bolt material properties could employ the
 method, but the test is not sufficiently refined to specify limits
 and procedures to be incorporated in a drawing or specification for
 general inspection.

CONCLUSIONS - Continued

- 3. A magnetic comparison method similar to that employed in the segregation program could be used by contractors as a means to determine uniformity of components within individual heat lots, but not as a final or in-process inspection. Magnetic data gathered in conjunction with destructive examinations would be helpful in controlling process variables.
- 4. Magnetic nondestructive tests in themselves did not correlate directly with bolt material properties. Each magnetic investigation initially appeared to offer good correlation but was found in later studies to be influenced by different heat-treat practices and procedures used by contractors. Magnetic permeability tended to increase with increasing percentages of free ferrite in the core and to decrease with higher core hardness; it was shown to be affected also by surface hardness and tempering time and temperature to a great extent. Retentivity and coercive force measurements indicated correlation with core hardness within individual heats of bolts but were shown to be more affected by tempering temperature than by core hardness. Distortion in the negative portion of wave form patterns correlated well with high core hardness when bolts were not highly tempered or retempered.
- 5. Simulated impact tests at ambient and cold temperatures indicated that bolts with high core hardness fractured with the least number of impact blows and at the lowest heights for most part; those within specification and those with higher percentages of ferrite in the core exhibited the best impact properties. The presence of free ferrite, however, makes the core susceptible to fatigue failure.

RECOMMENDATIONS

It is recommended that:

- l. A study be continued by Research and Materials Laboratories to determine the effectiveness of Rockwell C and D hardness measurements for estimation of bolt lug area core hardness (method has proved reliable to date on similar receiver studies).
- 2. Destructive examinations be continued at this time as in-process control of bolt quality.
- 3. Contractors be urged to use the magnetic permeability test to control heat-treating practices.

I. Introduction

This program arose as a result of an evaluation made on the metallurgical characteristics of M14 bolts and receivers involved in failures at Fort Benning, and from material currently supplied by all contractors for these items. This evaluation was requested at an M14 Task Group meeting held at Springfield Armory 28 December 1960 to determine the cause of four serious malfunctions of the M14 rifle reported by Fort Benning on 15 December 1960. During the investigation of the Fort Benning malfunctions, a "Code HG" receiver fractured on firing the first proof round. Metallurgical reports given at the meeting indicated that two major factors were immediately apparent: the use of improper receiver material and inadequate heat-treatment of bolts. Separate studies were conducted on many phases of the problem including ammunition, design, manufacturing and inspection procedures. In addition, malfunctions necessitated the requirement for nondestructive methods to test components insuring a high degree of confidence in the weapon and its component parts. Springfield Armory Report SA-TR19-1506 dated 7 November 1961 summarizes results of nondestructive test investigations conducted on Mi4 receivers; this report details the test studies made on M14 bolts.

Subsequent investigations on production bolts and observation of process methods employed by contractors indicated a most complex problem. Both gas and liquid carburizing methods were used in manufacture. Variations in equipment and heat-treating practices at different plants plus variations introduced into components in an attempt to salvage otherwise rejected parts due to skipped operations, distortion, and inadequate heat-treatment resulted in extreme variations in material properties. Process variables included wide differences in carburizing time and temperature, carburizing medium, and carbon potential resulting in different case depths, structure and hardness; type and speed of quenching oil together with different temperature, circulation, and degree of agitation; choice of tempering time and temperature to meet hardness requirement.

Establishment of acceptance criteria was extremely difficult because the number of failures had been small and actual conditions producing failures were not known. Bolts had not only variations in structure, differences in case and core hardnesses, and depth of case but also machining deficiencies, poor surfaces, lack of fillets, and other stress raisers. Probability was high that failures only occurred when some combination of conditions existed in the component.

REPORT SA-TR19-1507

I. Introduction - Continued

For clarification of acceptance criteria, bolt specification requirements were reviewed and additional requirements of core structure and core hardness imposed. Requirements which formed the basis for nondestructive tests were as follows:

Material: 8620H Resulphurized Steel (Carburized)

Case Hardness: Rc 54-59
Core Hardness: Rc 35-42

Case Depth: .015-.020 inch
Temper Temperature: 425°F (max)

Core Structure: 10% Free Ferrite (max)

II. Investigations, Bolt Malfunctions at Ft. Benning and at "Code HG" Plant

A. Procedure

The following bolts of 8620H steel composition which failed were subjected to visual and magnetic particle inspection, dimensional analysis, and metallographic examinations:

Malfunctions at Ft. Benning

Rifles 19453, 19478, 19391 from "Code WH" Rifle 19656 from Springfield Armory

Malfunction at Code HG" plant

Rifle 73293 from "Code HG"

B. Results

1. Visual and Magnetic Particle Inspection

a. Bolt, Rifle 19453

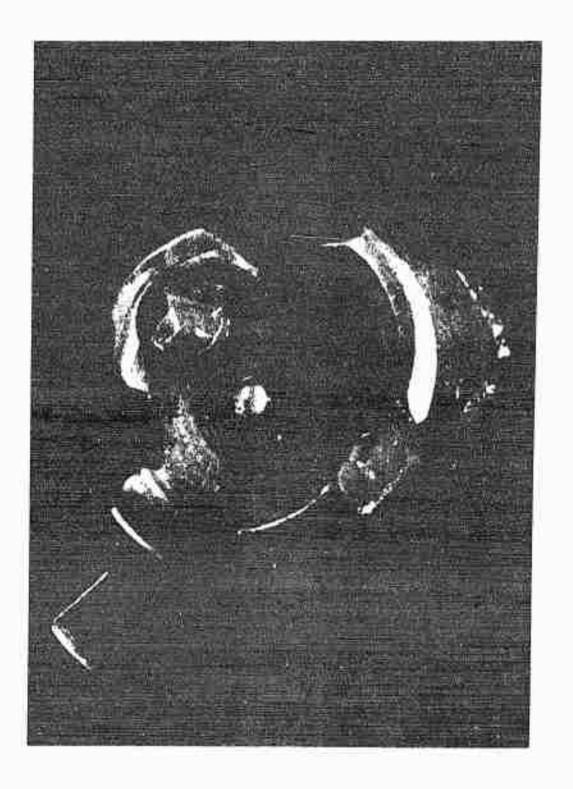
The right lug was sheared off completely. The origin of the fracture appeared to be at the rear radius of the lug. Cracking also initiated at the rear radius of the left lug extending diagonally into the head and terminating at the cartridge seat area (Figures 1 and 2). Fracture (Figure 3) initiated in the locking lug radius and progressed by fatigue to a depth of 0.060 to 0.100 inch when catastrophic failure occurred.



SPRINGFIELD ARMORY - ORDNANCE CORPS FRACTURED BOLT HEAD Rifle, 7.62mm, M14 - "Code WH", No. 19453

Figure 1

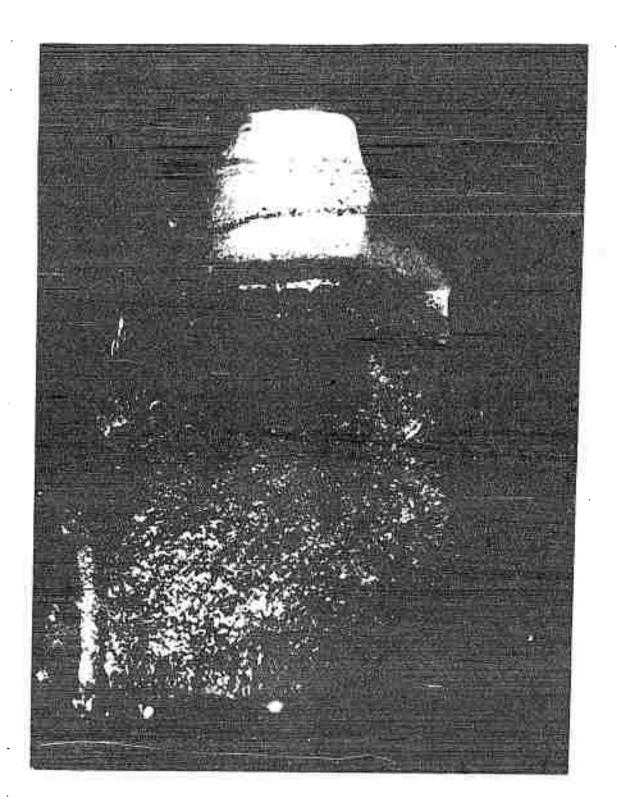
Neg: 19-058-1391/ORD-60



Neg: 19-058-1392/ORD-60

SPRINGFIELD ARMORY - ORDNANCE CORPS DAMAGED BOLT FACE Rifle, 7.62mm, M14 - "Code WH", No. 19453 Figure 2

-11-



SPRINGFIELD ARMORY - ORDNANCE CORPS FRACTURED BOLT Neg: 19-058-1393/ORD-60

Showing fracture surface of broken right locking lug Rifle, 7.62mm, M14 - "Code WH", No.19453

Figure 3

B. Results - Continued

b. Bolt, Rifle 19478

Excessive wear was noted at the bottom front face of the left-hand lug. Crack indications were observed across half the rear fillet of the right-hand lug.

c. Bolt, Rifle 19391

The left-hand lug was almost completely sheared. Magnetic particle indications of two parallel cracks extended across the radius of the right-hand lug with one extending around the corners.

d. Bolt, Rifle 19656

A triangular section approximately 7/8-inch long was broken off at the base of the ejector pin hole. Magnetic particle tests indicated cracks in the fillets of both lugs. Considerable wear and indentation were present on the rear face of the left-hand locking lug.

e. Bolt, Rifle 73293

Magnetic particle inspection revealed indications of cracks along the body radius of the left-hand lug extending to the chamfered corner. The bottom of the right-hand lug displayed abnormal paening from contact with the receiver lug. Indentation at the face of the left-hand locking lug was quite severe for firing one proof round.

2. Dimensional Analysis

a. Bolt, Rifle 19453

A dimensional check in the location of the locking lug surfaces indicated a misalignment of 0.001 inch over the permissible 0.002 inch. The fillet at the base of the left-hand lug was 0.006 inch. This is below the specified 0.020-0.010 inch.

b. Bolts, Rifles 19478 and 19391

No dimensional checks were made.

c. Bolt, Rifle 19656

Bolt had the forward edges of the locking surfaces approximately 0.003 inch forward of the drawing requirements and the rear edges missligned by 0.0025 inch.

2. Dimensional Analysis - Continued

d. Bolt, Rifle 73293

No dimensional check was made.

3. Metallographic Examination

Sections cut from the locking lugs were used for all metallographic specimens prepared from this group. Specimens were examined in the as-polished condition to determine cleanliness of steel and subsequently in the etched condition. The material in all the bolts appeared to be reasonably clean and free from objectionable inclusions, except for bolt 19656 which exhibited a heavy group of aluminum oxide inclusions. Tabulation of results obtained in metallurgical examinations are shown in Appendix A, Section 1.

a. Bolts, Rifles 19453, 19478, and 19391

These failed bolts contained approximately 50 per cent producted ferrite in the core (Figure 4). Because of its occurrence with a microstructure containing a high percentage of martensite and low-temperature transformation products, it was concluded that these bolts had been held below, and quenched from, slightly below 1520°F, the AC3 transformation temperature for 8620 steel. This conclusion was substantiated when Task Force groups reported that "Code WH" procedure involved carburizing followed by slow cooling, and reheating to 1475°F-1500°F for the final quenching operation.

b. Bolt, Rifle 19656

The microstructure appeared to be normal, i.e., characteristic of that obtained by Springfield Armory production heat-treating procedures (Figure 5). The core displayed small amounts of proeutectoid ferrite, 5 per cent maximum, with the remainder about evenly divided between upper and lower transformation products.

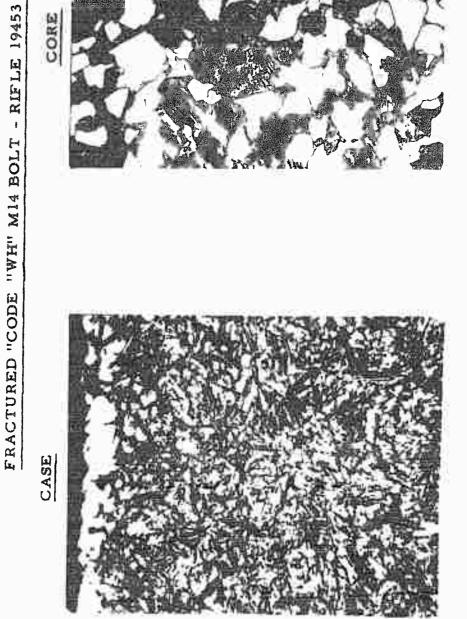
c. Bolt, Rifle 73293

The microstructure in the core consisted mainly of martensite and lower bainite with a small percentage of upper bainite and traces of free ferrite. The case contained approximately 20 per cent retained austenite to depths of 0.004 inch. Photomicrographs of the case and core together with the crack observed in the rear filler of the left hand lug are shown in Figure 6.

CORE

FIGURE

PHOTOMICROGRAPHS DISPLAYING CASE AND CORE MICROSTRUCTURES

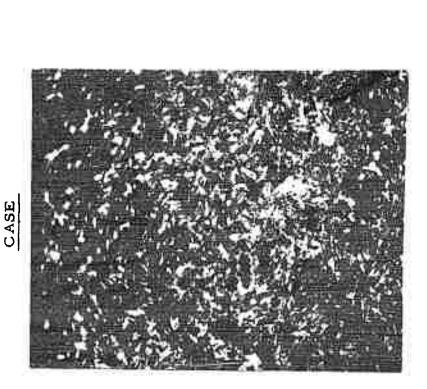


Etchant: Nital Mag: 1000X

FIGURE 5

PHOTOMICROGRAPHS DISPLAYING CASE AND CORE MICROSTRUCTURES

OF SPRINGFIELD ARMORY M14 BOLT - RIFLE 19656



CORE



Etchant: Nital Mag: 1000X

III. Investigations: Nondestructive Hagnetic Test Studies

Many varied nondestructive magnetic test studies were conducted at the Armory in an attempt to develop adequate test methods for bolt inspection. In connection with tests, a great number of bolts were sectioned and metallurgically examined to determine structure, hardness, and case depth data. Each magnetic investigation required additional destructive examinations because once sectioned, the bolts with then known properties could not be used. The bolt section used for metallurgical examinations in all studies is shown in Figure 7. Watertown Arsenal personnel assisted the Armory in metallurgical examinations of bolts.

A. Magnetic Permeability Comparisons

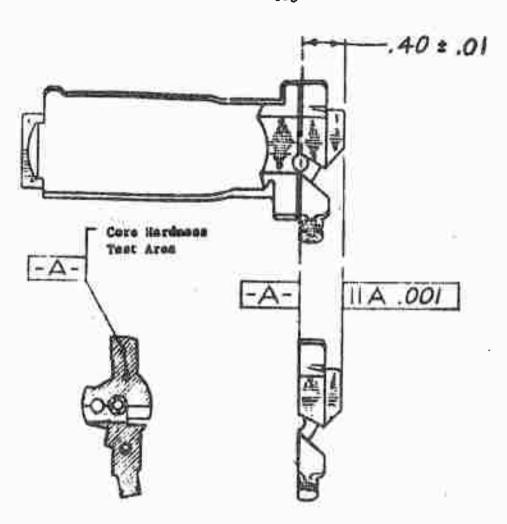
1. Equipment Employed

In the initial work, magnetic comparator type equipment was employed. The equipment is shown in Rigure 8. Basically, it contained a 60 cps generator, a ruit of similar coils, an amplifier, and filter and detector circuits for indicating the resultant coil output voltage. Each of the similar coil units contained a primary and a secondary winding. The primary winding of each coil applied an a.c. magnetizing field to the sample placed in the coil. The secondary windings were connected in series opposition so that only the difference-voltage between the two secondaries was measured by the indicator circuit. When like comples with identical magnetic properties are placed within the coils, the induced voltage in each secondary winding is equal and the resultant output voltage is zero. In the actual test, a reference bolt was placed in one coil where it remained throughout the test. Bolts being compared were then inserted in the other coil.

2. Results

Bolts heat-treated by gas and liquid carburizing processes were tested. Bolts selected for tests were taken from lots known to contain varying percentage of free rewrite in the core, others with high core hardness, and some within specification requirements. Four magnetic comparison variations were studied to determine which one revealed widest differences with bolts examined. Wave forms were noted in order to study phase shifts and presence of harmonics. Filter networks made it possible to measure the resultant secondary output in terms of the fundamental frequency only (60 cps), the third harmonic only (180 cps), the fundamental plus all harmonics, and all harmonics with the fundamental filtered out.

Figure 7

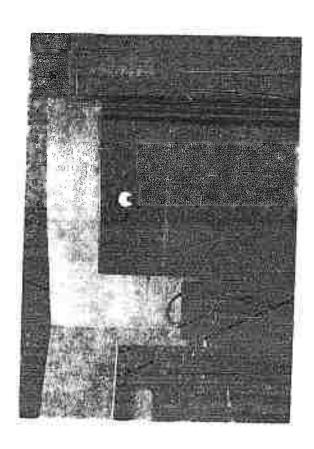


Test Specimen for Case Depth, Free Ferrite, and Core Hardmess Teste

Bolts shall be sectioned as indicated above. Surfaces shall be ground (fine grind) parallel as shown. Surface A shall be prepared for tests in accordance with SA STD-104, Test Mathod No. 102 (Steps 3 (a) and 3 (b) not required . above procedure).

(Extreme care should be exercised in cutting bolt so as not to burn, temper, or change microstructure of any surface.)





A. Magnetic Permeability Comparisons - Continued

Widest magnet!: differences were noted employing the fundamental wave pattern only (60 cps) and the fundamental plus all harmonics. Metallurgical examinations revealed wide variation in core properties. Magnetic readings indicated a general grouping with properties, but with unaccountable differences within each group. Readings primarily representing a permeability measurement appeared to show that permeability increased with increasing percentages of free ferrite in the core and decreased with higher core hardness; however, too many exceptions were noted to assume any correlation.

B. Measurements of Basic Magnetic Properties

Because permeability appeared to offer insufficient correlation with core hardness, studies of other measurable magnetic properties; such as retentivity, coercive force and residual flux density were undertaken.

1. Retentivity Measurements

a. Equipment Employed

Retentivity, the flux density remaining after a magnetizing current sufficient to cause saturation has been applied and reduced to zero, was measured with laboratory equipment comprising a d.c. power supply, a magnetizing coil and a gaussmeter. Arrangement is shown in Figure 9. In addition, the opposing current required to bring the retentivity to zero was recorded. Measurements were extremely sensitive to probe position.

b. Results

A plot of opposing current (-I $_{\rm H}$) versus Rockwell C core hardness data on bolts from "Code Wh" heat-treated as a group is shown in Figure 10.

Graph indicates good correlation of (-I_{II}) with averaged core hardness on this group of bolts. (Infortunately, however, when bolts from various heat-treat processes were tested and metallurgically examined, data did not plot linearly. Numerous results did not fall on the curve. Compilation of opposing current data hardness measurements, and microstructure examinations are shown in Appendix, Section 2. Data show that very hard bolts (Rc44-46) which had been retempered gave (I_{II}) values of 350-370 milliamperes. Bolts which were not retempered and had hardness (Rc 37-40) measured 400-410 ma. Another group retempered at 530°F with core hardness (Rc 41-43) had (-I_{II}) data in the vicinity of 265 ma. It was thus concluded that the measurement was more affected by tempering temperature than core hardness.

ARRANGEMENT for RETENTIVITY MEASUREMENTS

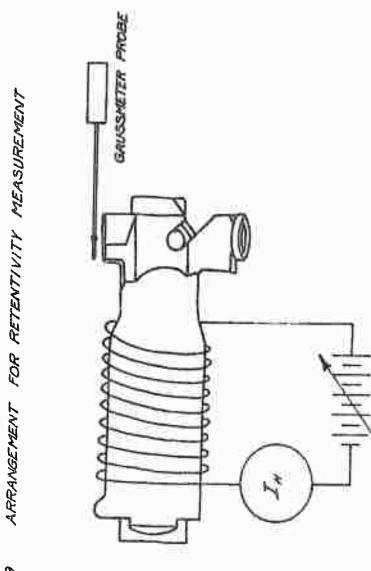
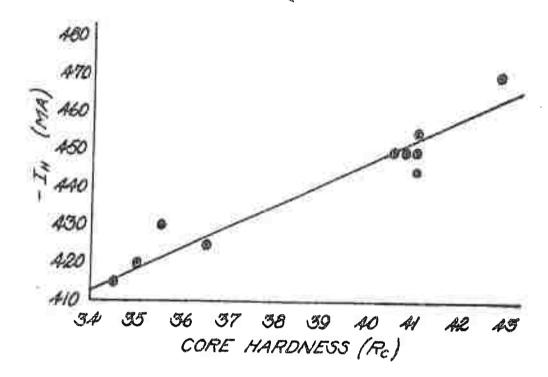


FIGURE 9

FIGURE 10 OPPOSING CURRENT VERSUS CORE HARDNESS ON "CODE WH" BOLTS



RETENTIVITY VS CORE HARDNESS MEASUREMENTS

2. A. C. Hysteresis Loop Measurements

a. Equipment Employed

A. C. hysteresis loop measurements were next made in an effort to correlate core hardness. A 60 cps generator was used to induce an A. C. field in a u-shaped, high permeability, laminated core. A secondary winding encircled the bolt. The bolt was placed against the pole faces of the laminated core; thus the magnetic circuit was completed. By means of a phase shifting network, a hysteresis loop was displayed on an oscilloscope. The experimental arrangement is shown in Figure 11.

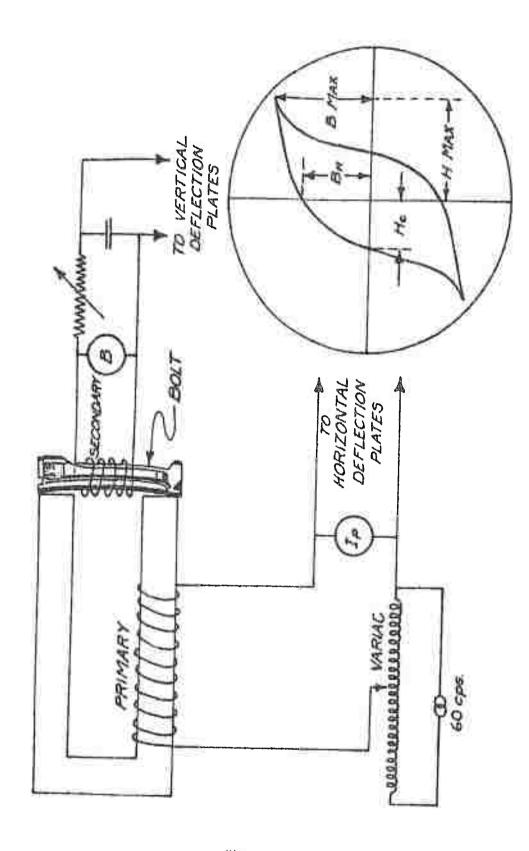
b. Procedure

Coercive force (H_C) and residual flux density (B_R) measurements were recorded on nearly 200 bolts; first, at saturation flux density; then, at a constant flux density below saturation. The greatest sensitivity was indicated with the use of the latter. Before destructively examining any of these bolts, magnetic readings were recorded with the use of a previous magnetic comparator setup in an attempt to gather as much data on this group of bolts as possible.

c. Results

Coercive force, residual flux density, and core hardness data obtained on eighteen "Code WH" bolts are listed in Table 1. Additional metallurgical data compiled on these bolts are shown in the Appendix, Section 3.

EXPERIMENTAL ARRANGEMENT FOR A.C. HYSTERESIS LOOP MEASUREMENTS FIGURE 11



MEASUREMENTS HYSTERESIS LOOP ARRANGEMENT for A.C. EXPERIMENTAL

Coercive Force, Residual Flux Density, and Core Hardness Data
on "Code WH" Bolts

Bolt Identity	Constant Current a	Magnetizing bove Saturation BR x 2	Constant Below Sat		Core Hardnes
66118A -8	3.75	5.0	3.55	B _R x 2	Rc 41.5-43.5
-18	3.75	5.4	3, 35	8.75	42-43
• -9	3.7	5.4	3, 35	8.8	42.5-44
-12	, 3.8	5.25	3.45	8.8	41.5
-11	3,8	5.2	3.4	8.9	40.5-42.5
-16	3.8	5.4	3.35	8.6	40-42
-15	3.7	5.3	3.3	8.8	40,5-42,5
≈13	3.75	5.4	3.3	8.7	39.5-42
-10	3.7	5.6	3.2	8.7	40-42
- 5	3.7	5,5	3.2	8.75	40-42
- 3	3.8	5.55	3.3	8.7	38-40.5
~1	3.8	5.45	3, 2	8.5	38-41
on 4	3.7	5.3	3 .3	8.8	36.5-38
~17	3.7	5.4	3. 2	8.7	34,5-39
-2	3.7	5.3	3.2	8.6	32-40
-14	3.7	5.5	3.1	8.6	35-37.5
~7	3.8	5.2	3.15	8.7	32-39.5
- 6	3.75	5.6	3.1		34-37
					1 '

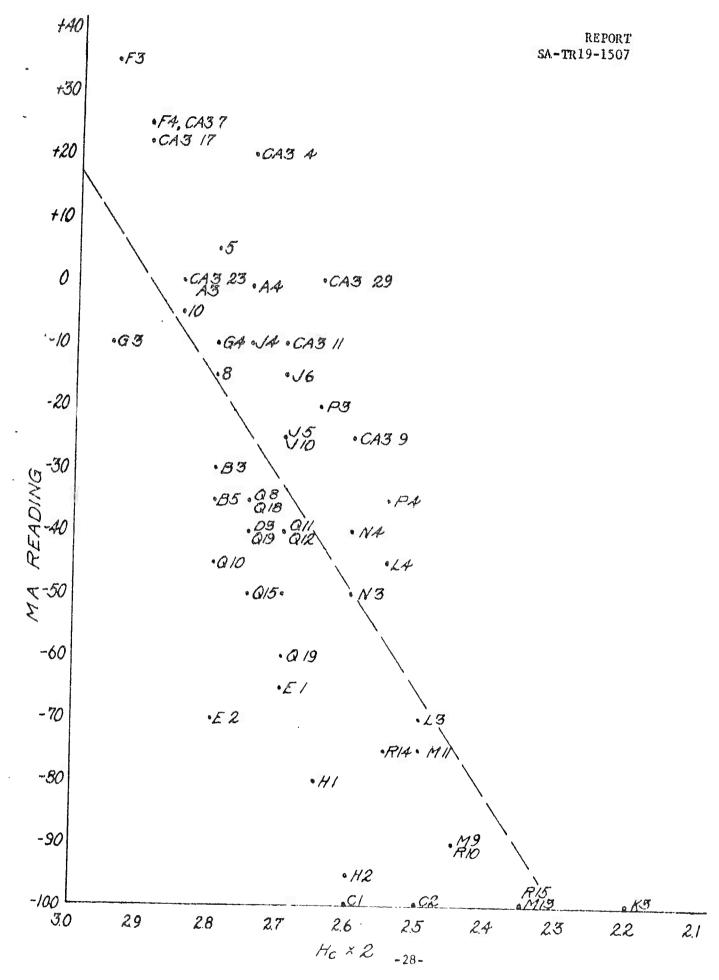
In total approximately 60 bolts were sectioned and the metal-lurgical results most carefully compared with the collected magnetic data. Promising correlation of coercive force versus core hardness on this group of bolts was indicated with data obtained at constant flux density below saturation. However, as with retentivity studies, in measurements made on retempered bolts, it was shown that coercive force was more affected by tempering temperature than core hardness. Table shows coercive force and hardness data on Armory bolts from heat lot CA3 tempered at 400°F, and "Code HG" bolts identified CA05 retempered at 530°F.

Hysteresis Loop and Hardness Data on Bolts Normally Tempered and
Retempered at High Temperature

	olt dentity	Constant I _H Above Satur H _C x 2		Constant Fl Below Satur H _C x 2	•	Range Core Hardness Rc
CA3	-4	4.0	5.9	2.7	8.0	41.5-42
	-9	3.9	6.0	2.6	7.8	37-41
	~25	3.9	5.9	2.7	7.8	39-40
CA05	-1	2.9	5.9	1.7		42-43
	2	2.8	5.95	1.65		43-44
	3	2.9	5.9	1.7		44,-45
	4	2.8	5.9	1.65		41-42

Previous studies appeared to show that coercive force increased with hardness; whereas, results of the present studies show that coercive force was more influenced by retempering at high temperatures than by core hardness. Bolts of higher core hardness had coercive force decrease when retempered.

A plot of coercive force versus magnetic comparator readings appeared significant (Figure 12). It was possible for a boundary line to be drawn on the data plot which divided for most part acceptable components from deficient ones. Bolts containing a high percentage of



free ferrite were separated from those which had been highly tempered or retempered. Previous magnetic comparisons had not differentiated these conditions. A 100 per cent correlation was not obtained; however, a few gas-carburized bolts (P3 and P4) with comparatively low surface hardness and very high core hardness upset the correlation in that these plotted within a group of acceptable bolts. Metallurgical results comprising surface and core hardness, microstructure, and case depth measurements on bolts plotted are shown in Appendix, Section 4.

3. Hardness - Magnetic Permeability Investigation

The noted discrepency in correlation proved most important because greater concentration was now given to the surface hardness variable. Because flux density is at a maximum on the bolt surface and decreases in an exponential manner into the core, it seemed most reasonable to more carefully consider surface hardness when examining the magnetic data with respect to core hardness.

Table 3 indicates that magnetic readings were affected greatly by surface hardness. Rockwell C core hardness was essentially the same, surface hardness varied, and magnetic readings differed by approximately 85 points.

TABLE 3

Effect of Surface hardness on Magnetic Readings

Magnetic Reading	Surface Hardness Rc	Body Core Hardness Rc
+25	62	38.5, 39, 39, 42, 42
-31	58	38, 39.5, 39.5, 40, 41.5
~62	55. 5	39.5, 40, 41, 42, 42.5

Table 4, however, likewise indicates that core hardness influences magnetic readings. Bolts of similar or identical surface hardness were selected and magnetic readings and core hardness were compared.

TABLE 4

Effect of Core Hardness on Magnetic Readings

Magnetic Reading	Surface Hardness Rc	Body Core Hardness Rc
-3	56-56	43, 43, 43, 43.5, 44
-4	55~57	42.5, 43, 43, 44, 45
-20	55.5-57	37, 38.5, 39, 39, 39.5
~27	55-56	36, 39, 40, 40.5, 40.5
-42	56-56	36, 37, 38, 38, 39
-62	55-56	36, 36, 36, 37, 37.5

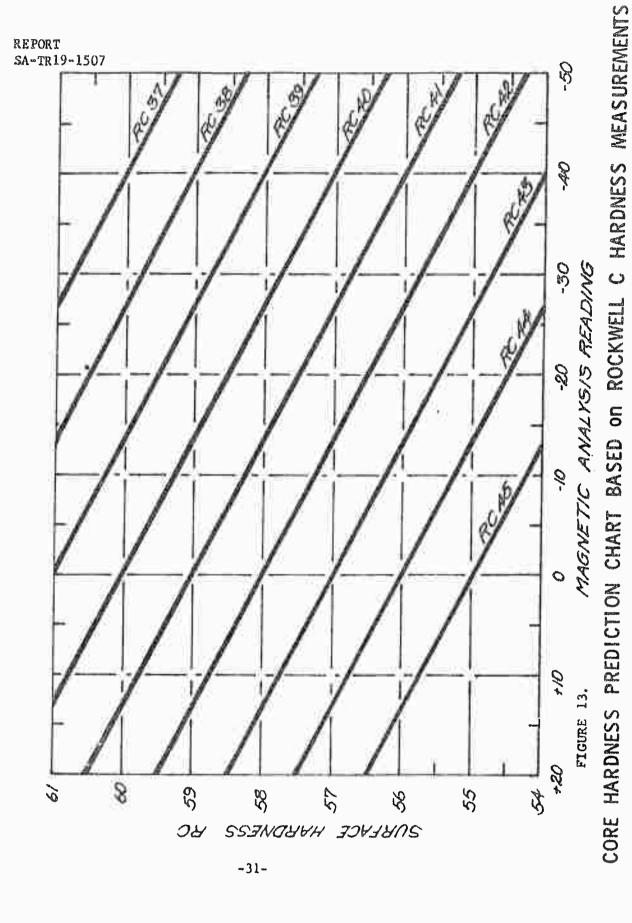
Magnetic and hardness data were next plotted and studied. A chart relating surface hardness, magnetic reading, and core hardness was developed. With surface hardness and magnetic reading known, it is possible to predict core hardness from this chart (Figure 13).

C. Wave Form Pattern Studies

At this point in the investigation 1800 bolts were received from Raritan Arsenal; these bolts required some type of segregation because of the urgent need for supplying the field.

Magnetic permeability and Rockwell C surface hardness measurements were recorded on all 1800 bolts. Twenty-five of these bolts were selected and a prediction of core hardness made. Twenty-four provided an accurate determination of core hardness within \pm 1.5 points Rockwell C. The other was 5 points Rockwell C harder than predicted.

In the conducting of the magnetic permeability tests, similar characteristic wave form patterns were observed on the oscilloscope. Three basic patterns, with many variations of these, were apparent. Designated pattern 1 was an undistorted sine wave; pattern 2 had third harmonic distortion; and pattern 3 indicated severe distortion of the 60 cps fundamental on the negative portion of the display. Hardness measurements and microstructure examinations were made on bolts with above characteristic patterns. Table 5 lists hardness, magnetic reading, and pattern information gathered on 19 bolts. Other metallurgical data on these bolts, and additional magnetic and metallurgical investigations made in this study are compiled in Appendix, Section 5.



C. Wave Form Pattern Studies - Continued

TABLE 5

Data on Bolts with Basic Wave Form Patterns

Bolt Identity	Magnetic Reading	Basic Wave For Pattern	Surface Hardness Rc	Body Core Hardness Rc	Lug Core Hardness Rc
67988	-15	1	57.5~58	38, 38, 39, 39, 39	39, 39, 39, 5, 40, 5, 42
69216	-18	1	59-59	39, 39, 39, 40, 41	37, 39, 40, 40, 5, 41
77533	-32	1	58-59	36, 36, 36. 5, 37, 37	37.5,38,38,40,40.5
78153	~50	1	57.5-59	36, 36, 36. 5, 37, 37	36, 37, 38, 40, 40. 5
75089	≈92	1	54.5-56	37, 37, 37, 37, 39	37, 38, 39, 39, 5, 42
69832	+20	2	59	39, 40, 40, 42, 43	42, 42, 43, 43, 43.5
7600 2	+12	2	61.5-62	38, 39, 39, 41, 42	36, 36.5, 37.5, 38.5,
708 25	0	2	55.5-56	36, 38, 38, 38, 40	36, 37.5, 38, 38, 42
70190	~2	2	58~58	39, 39, 39, 40, 41	40, 40, 42, 42.5, 42.5
68722	-24	2	58.5~59	36, 36, 37, 38, 39	37, 37.5, 38, 40, 40
71355	-27	2	57.5-58.5	37, 38, 38, 39, 41	38, 39, 39.5, 40, 41
73237	-33	2	58	36, 37, 37, 39, 40	35.5,35.5,35,5,36 37.5
77109	-3 6	2	57-58,5	36, 37, 37, 40, 40	35.5, 36, 36, 36.5, 37
70400	-10	3	57.5-58	41,44,45,45,45	43, 45, 45, 45, 46
69981	-12	3 .	57.5-58	42, 43, 45, 45, 45	44, 44. 5, 45, 45, 45
74387	-14	3	56.5-57.5	42, 43, 43, 43, 44	43.5, 43.5, 44, 44.5; 44.5
74823	~15	3	53.5~56	43, 45, 45, 46, 46	42.5, 43.5, 44, 44, 43
77188	-27	3	58.5-59	42, 42, 43, 43, 43	41,43.5,43.5,44,44
76924	-75	3	56.5	42, 45, 45, 45, 45	44,45,45,46,46

C. Wave Form Pattern Studies - Continued

Results show that basic patterns offer some correlation. Bolts with basic patterns 1 and 2 have core hardness within specification; bolts with pattern 3 consistently indicate high core hardness above specification requirements.

In order that pattern variations be studied further, approximately 150 oscillograms were taken of the differing degrees of distortion. The corresponding bolts were sectioned and metallurgically examined. Six obvious patterns and their variations were correlated with material properties. Patterns correlated are shown in Figure 14; metallurgical data are compiled in Appendix, Section 6.

D. Bolt Segregation Tests

. 1. Procedure

Based on results of all studies, a combination test method employing magnetic permeability readings, Rockwell C surface hardness measurements, and oscilloscope wave form patterns was used in bolt segregation. A Rockwell C hardness measurement was taken on the rear part of the bolt or on a lug area. The bolt was then subjected to magnetic test wherein amplitude and pattern were noted. The combination was evaluated and bolts were segregated into the following groups:

- Group A Core hardness Rc 35-42.5, core structure ferrite less than 10 per cent.
 - B Core hardness Rc 42.5-45.
 - C Surface hardness outside Rc Specification.
 - D High temper or retemper.
 - E Core hardness greater than Rc 45.
 - F Core hardness less than Rc 35.
 - G Core structure excess free ferrite.
 - H Rejected other unfavorable conditions.

2. Results

A total of 33,808 bolts was inspected at Springfield Armory amploying the combination test method. Segregation into each group was as follows:

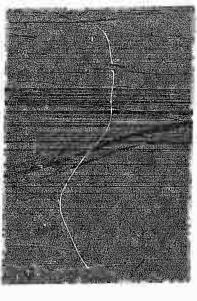
WAVE FORM PATTERNS CORRELATED WITH MATERIAL PROPERTIES



ACCEPTABLE



BORDERLINE ACCEPTABLE



HIGH CORE HARDNESS REJECTABLE



HIGH PERCENTAGE FERRITE REJECTABLE



DECARBURIZED REJECTABLE



HIGHLY TEMPERED OR RETEMPERED

D. Bolt Segregation Tests - Continued

Group A - 6,827 B - 20,021 C - 660 D - 3,399 E - 94 G - 587 H - 2,220 13,808

Based on decision of higher authority, Groups A and B represented acceptable groups for reassembly into weapons. As such, 26,848 bolts were salvaged.

E. Simulated Impact Tests

1. Procedure

In an effort to evaluate various groups of bolts segregated by magnetic methods and to determine if correlation existed between component impact strength and its metallurgical properties, impact tests were conducted employing a Tinius Olsen Drop Tester. To this end a fixture was designed and fabricated to hold the bolts in a manner similar to that of the weapon receiver. The component rested vertically in the fixture on its rear locking lug faces. A cap held in place by locking pins rested on the front locking lug faces. Through a hole in the cap, a piston was inserted in contact with the bolt cartridge seat. Drop tests were conducted at ambient and cold temperatures from various fixed heights and increasing heights with 10- and 20-pound hammers. Bolts for tests were selected from evaluations made of surface hardness, magnetic reading and wave form pattern.

2. Results

Initial tests made with a 20-pound hammer and an impact force of 40 foot-pounds were inconclusive in that the test was considered too drastic. All bolts failed after a single or only a few blows.

Bolts with patterns characteristic of structures and core hardness within specification (Group A), those with core structures of varying percentage of ferrite (Group G), and those with core hardness higher than specification hardness (Group B) were next tested with an impact of 10-pound hammer at 3 foot height. Results in Appendix, Section 7 show that bolts of highest core hardness fractured with the least number of blows for most part. Bolts within specification and those with higher percentages of ferrite in the structure exhibited the best impact properties. From experience with initial failures, it was apparent that low core hardness and/or free ferrite in excess of 10 percent produced a weak component which will fail prematurely in fatigue.

E. Simulated Impact Tests - Continued

Highly tempered or retempered bolts, because of the large quantity found in segregation, were next studied. Tempering in itself is generally considered beneficial but for 8620H material it was found that bolts were approaching a "blue brittle range" with the temperatures used. Charpy impact tests had shown that impact strength dropped sharply on bolts that had been tempered at 530°F. Additional magnetic and simulated impact studies were attempted in order to evaluate acceptable conditions.

Because highly tempered and retempered magnetic patterns had large amplitudes with variations hard to detect, double exposure oscilloscope records were taken on bolts studied. The first exposure was taken with the bolt in its proper position within the coil; the second exposure was made with the bolt pulled out until the meter read zero. With this procedure, four basic patterns designated Al, Bl, Cl and Dl were noted. Basic patterns are shown in Figure 15.

Simulated impact tests made on bolts with these various patterns employing an impact of 30 foot-pounds indicated that bolts with patterns Al and Bl withstood the greater number of impact blows. Metallurgical results indicated that pattern Al had fairly high percentages of free ferrite in the core (10 to 25%). Bolts with patterns Cl and Dl failed quickly (1-3 blows); corresponding core hardness was high. Impact test and metallurgical data are compiled in Appendix, Section 8.

Tests were also conducted at temperatures approaching -65°F. The fixture used to align bolts was incased in dry ice and acetone. Bolts were soaked in the bath before insertion in the fixture. The impact test machine was set so that after impact the hammer was raised an additional inch. Successive impacts were thus increasingly higher. Results (Appendix, Section 9) were quite similar to those obtained at ambient temperatures. Bolts with higher core hardness fractured for most part at the lowest heights; bolts with higher percentages of ferrite in the core fractured at the highest heights.

Although results indicated that bolts with high percentages of ferrite in the core gave best impact results, the presence of free ferrite makes the core susceptible to fatigue failure.

WAVE FORM PATTERNS OF HIGHLY TEMPERED Bl DI OR RETEMPERED BOLTS Al ៊ 15 FIGURE

FINAL AND IN-PROCESS INSPECTION

Although results and progress on the bolt segregation program were most successful, it is felt that the combination of tests with surface hardness, magnetic reading, and wave form pattern is too complicated to employ as an in-process inspection method. Engineers who are experienced with the problem and have observed wave form pattern differences and resultant material properties are able to make suitable segregations but the test is not sufficiently refined nor of relative case to specify limits and procedures which could be incorporated in a drawing or specification for general inspection.

A test method employing a combination of Rockwell C and D hardness measurements on the receiver has proven extremely reliable for estimation of core hardness. Studies are now being made to determine the reliability as regards bolt inspection. A fixture has been designed for taking hardness measurements on the bottom of the left lug area. Results will be reported upon termination of studies.

A - Graphs

B - Distribution

REPORT SA-TR19-1507

		GRAPHS	Page
Section	1.	Metallurgical Data on Bolts which Malfunctioned at Fort Benning and at "Code HG" Plant	41
Section	2.	Magnetic and Metallurgical Data on Bolts in Retentivity Study	43
Section	3.	Metallurgical Data on Bolts in A.C. Hysteresis Loop Measurement Study	46
Section	4.	Metallurgical Data on Bolts in Coercive Force - Magnetic Permeability Study	48
Section	5.	Magnetic and Metallurgical Data on Bolts in Wave Form Pattern Study	53
Section	6.	Metallurgical Data on Bolts in Oscillogram Study	56
Section	7.	Impact and Metallurgical Data on Bolts in Impact Test Study	60
Section	8.	Impact and Metallurgical Data on Tempered Bolts in Impact Test Study	62
Section	9.	Impact and Metallurgical Data on Bolts in Impact Cold Test Study	64

Section 1

Metallurgical Data on Bolts which Malfunctioned at Fort Benning and at "Code HG" Plant

REPORT SA-TR19-1507

56-57 56-42 58-42 56-58 56-57		OSTALLTUBE	CASE	TTE WATERSTIE DEPTH HETMINED REMARKS	ريا	REW 020	255	3	4	OS TRIANGULAR PIECE (VERT IRREGULAR) BRONEN FROM ALONG COST. TO .004" ELECTOR PIN HOLE.
58-60 35 55-38 56-57 87-38 58-42 56-57 87-38 58-42 54-55 40-43 38-42		MICADSTA		PERMITE BAIN		40-50% 2-5%	201-5 20% 2-10%	50% 15-25%	0.5% 40.8%	
HARONE SUMPRICE DAR LUG TR. 58 -60 35 56-59 40.5-42 56-57 25-27 56-57 37-38 54-55 40-43		SS	1000	Re		85-38	39-41	37.5-33	38-42	38-42
58-60 58-59 56-57 56-57		MAKONE	CORE LUM	Pe	1 2	3	40.5-42	25-27	37.38	40-43
		7	SURFACE	Ro	TB-//	0	58-59	55-58	56-57	56-55

Section 2

Magnetic and Metallurgical Data on Bolts in Retentivity Study

REPORT SA-TR19-1507

	REMARKS							RETEMPERED	PRIEMERED
CASE	RETAINED AUSTENITE	REM .019020 30-0% 10.00%	OLO-OLZ TRACES OF 100%	TESS GEORGE	30-10,8 70-02	TRACES	.018.019 1059 ONE		
5	DEPTH (INCHES)	020:-610:	.020-022	.020	6/0:-8/0	8/0:9/0	.017019	.017-020	.017020
TURE	290 W	REM	ì	*	*	٤	ž.	,,	ž.
MICROSTRUCTURE	FREE UPPER SITE AMITE BAINTE	30-50%	50-CO%	20-35%	5% MAX.	0-2%	0.5%	2-10%	0-5%
MICAC	FREE FERRITE	5-10%	8-12%	2-1%	22-1%	3-5%	0-3%	8-12%	5-10%
TING COPE	HARDNESSS Re	33-35-36	37.38-58-39	<i>52-25-35-35</i>	45-45-45-455	44-44-445-45	44.45.45.465	41-41-4-42	42-42-43-43
OMISONAO	CURRENT (-IN) (MA)	405	330	380	340	350	360	260	265
1708	IDENTITY	MRT JA	HRT-L3	HRT-LA	HRT- R15	HRT-R10	HAT-RIA	CA05-7	CA05-5

	807	OPPOSING	LUG CORE	l e d	1 < 1	CTURE		CASE
66/18 A 36 470 44-44-44 5-7% 6-20% REM .022022 66/18 A 12 465 41-41-41 5-7% 6-20% .022022 66/18 A 12 465 41-41-41 5-7% 5-20%	IDENTITY	(-IH) (MA)	HARONESS (Rc)	FREE	UPPER	MARTENSITE AND LOWER BAINITE	DEPTH (INCHES)	AUSTENITE :
66/18 A 12 465 44-41-41 5-7% 65/20% .020026 66/18 A 12 465 40-40-41-41 5-7% 20-3%		470	41-41-42-43	5% MAX		PEM.	.022023	55-20% 70 .003" 3
66/18 A 12 465 40-40-41-41 3-7% 20-35% "	1 K81199	465	14-14-14-14	3-7%	15-20%	"	.020-022	40-15% 70 .004."
66/18 A 5 450 40-40-40-44 5-10% 20-35% "		455	14-14-04-04	3-7%	20-30%	*.	.018020	30-15% 70 .003."
23 450 40-45-44 5-10% 15-20% <t< td=""><td></td><td>450</td><td>40-40-41</td><td>2-10%</td><td>20-35%</td><td>,,,</td><td>810710.</td><td>60-10% 70 .005"</td></t<>		450	40-40-41	2-10%	20-35%	,,,	810710.	60-10% 70 .005"
66/18 A 3/1 460 37-38-38-39 5-10% 39-65% "		450	40-45-45-44	5-10%	15-20%	*	.022023	35-25% 70 .003."
66118 A 15 445 40-40-41-41 5% MAK 15-25% <td></td> <td>450</td> <td>57-38-38-39</td> <td>2-10%</td> <td>30-85%</td> <td>*</td> <td>.020-021</td> <td>50-10% 70 .0025"</td>		450	57-38-38-39	2-10%	30-85%	*	.020-021	50-10% 70 .0025"
66/18 A 25 430 52-32-33-33 5-107 55-207		445	14-4-04-04	5% MAX.	15-25%	¥	710910.	10-15% 70 .005."
66/18 A 20 425 52-35-36-96 5-7% £5-357		430	52-32-53	2-10%	35-50%	,	.020-022	40-10% 10:024"
66/18 A 7 420 55-35-37-37 5-7% 20-30% " O/T0/9 66/18 A 2 416 35-35-37-37 3-7% 25-45% " O/G0/8 HR7 Q-8 405 45-45-46-46 3-5%		425	32-35-36-36	3-7%	25-35%	"	8/0-2/0.	45-35% 70 .0025"
661/8 A 2 416 35-33-33-33 3-7% £5-45% "	661184 7	420	85-35-37-37	3-7%	20-30%	"	610:-210:	40-15% 10.004"
HRT 9-8 405 45-46-466 8-5% 0-5% "	66118A	415	33-33-33	3-7%	25-45%	*	810-910	40-10% 70 .00%.
B-3 390 39-335-40-44 20-30% 5-10%	HRT	405	45-45-46-46.6	3-5%	0-5%	ì	6/0-8/0.	202 70 .002."
Q-/8 405 44-42-44.5-45 5-10% 5-15% "		330	39-395-40-41	20-30%	2-10%	ž	.023024	TRACES
Q-II 405 45-45-46-46.5 5-5% 0-5% ". OIG-OIG A-I 420 40-40-40 7-12% 10-20% ". OIG-OIG F-I 440 41-41-42-42 5-10% 16-20% ". OIG-OIG F-Z 425 37-37-37 10-17% 30-45% ". OIG-OIG F-Z 425 37-37-37 10-17% 30-45% ". OIG-OIG G-I 425 37-39-39-30 15-25% 55-10% ". OIG-OIG G-I 425 39-39-40-40 15-25% 52-10% ". OIG-OIG D-I 385 39-39-40-40 15-25% 52-10% ". OIG-OIG D-I 385 37-31-38-39 15-25% 52-10% ". OIG-OIG H-I 375 36-36-39-39 20-26% 7.74-66 ". OIG-OIG H-I 410 34-35-38-39 3-72% 35-36% ". OIG-OIG J-I 410 34-35-36 5-12% 35-36% ". OIG-OIG J-I 410 34-35-36 5-12% 35-36% 35-36% 35-30% J-I		405	4-42-42.5-45	2-10%	5-15%	ì	6/0-2/0	NOWE
A-1 420 40-40-40-40 7-12% 10-20% "		405	45-45-46-465	3-5%	0.5%	,,	8/0-9/0	60-10% 70.005"
F-1 A40 A1-A1-A2-A2 5-10% 15-20%		420	04-04-04-04	7-12%	10-20%	**	.0/5	10-5% 70 .002."
F-2 425 37-37-37-37 10-17% 30-40%	•	440	24-24-14-14	5-10%	15-20%	ž	710-510.	100 20 005 208 70
E-2 395 36-36-37-38 25-40% 5-10% "		425	37-37-37-37	1798	30-4-08	"	810:910.	100% 70:0015.
G-1 4/25 37-39-39-40 25-35% 16-25% </td <td></td> <td>395</td> <td>36-36-37-58</td> <td>25-40%</td> <td>2-10%</td> <td>*</td> <td>0/4-0/6</td> <td>100% 70.0015"</td>		395	36-36-37-58	25-40%	2-10%	*	0/4-0/6	100% 70.0015"
0-1 385 39-39-40-405 15-25% 572 MAK. "		425	37-39-39-40	25-35%	15-25%	ž	.0/6	100.001.20% 10
0-2 395 37-37-38-39 15-25% 5% MMX " .016017 H-1 375 36-36-37-37 40-50% 0-10% " .015016 H-2 370 37-38-39-39 20-26% 7RACES " .015017 J-1 410 34-35-38-39 3-7% 35-46% J-2 410 34-35-36 5-12% 35-30% " .015018		385	39-39-40-405	15-25%	5% MAX.	ž	080-810.	100% 75.0005"
H-1 375 36-36-37-37 40-50% 0-10% " .015016 H-2 570 57-38-39-39 20-26% 77ACES " .015017 J-1 410 34-35-38-39 3-7% 35-46% " .014016 J-2 410 34-34-35-36 5-12% 35-30% " .015018		395	37-37-38-39	15-25%	5% MAX.	"	7/0-9/0.	NONE
H-2 570 57-58-39-39 20-26% TRACES "		575	36-36-37	40-50%	0-10%	18	.0/50/6	TRACES
J-1 410 34-35-38-39 3-7% 35-45% " .014016 J-2 410 34-35-36 5-12% 35-50% " .015018		570	57-58-39-39	20-25%	TRACES	,,	710-510	NONE
J-2 410 84-34-35-36 5-12% 35-50% " 1015-018		014	34-55-58-39	3-7%	35-45%	*	3/0-4/0.	26-15% 70.002".
		410	34.34-35-36	5-12%	35-50%	×	.015018	35-25% 70 .004".

APPENDIX A

Section 3

Metallurgical Data on Bolts in A.C. Hysteresis Loop Measurement Study

T 19-1		2005
	REMA. THS	CAACK LUG . OOZU MISMATON III FILET CRACK . OIS OIM CRACK . OOZE GRAIN BOUNDEY CRACK . IN FILLET CRACK . OOZE GRAIN BOUNDEY CRACK . OOZE MISMATCH FLOUE MISMATCH AACH. IN CRACK . OOZ MISMATCH AACH. IN CRACK . OOZ
CASE	PERCENT PETAINED KSTENITE	010 012
MICHOSTRUCTURES	MARKENSITE MAD ADMER BRANITE	
MARDNESS	6	40-41 36.5-39 40-41 46.5-39 40-41 34-40 87 32-89.5 40-42 34-40 40-41 38-41.5 41-42 35-40.5 41-42 35-40.5
1- 1-	WILLIAM WAR	# # # # # # # # # # # # # # # # # # #

-41-

Section 4

Metallurgical Data on Bolts in Coercive Force - Magnetic Permeability Study

1181	19-1507 9xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx	POLICE PADIUS COUNTY CONSTITUTED	SEVERE PATING WFILLEY GRAIN BOWDEY CONSTITUENTS TO COCKE	SEVERE DEED PITTING (IN PLACE) SOUND. (CONSTITUENTS TO . DOUG!"	(SEVERE PITING IN FILLET TRACES OF GRANN BOUNDER CONSTITUTION	SEVERE DEEP PITTING IN	SEVERE CLEP PITING IN FILLET, TENCES OF SET	SEVERE FITTING IN FILLER TRACES OF SEAN BOUND.	SLIGHT PITTING IN FILLET		SEVERE SIAPHCE PITTING		SEVERE SUPPLIET		SOME PITTING GRAIN BOUNDET CONSTITUENTS TO ONE	SOME HEAVY PITTING	HEANY PITTING IN
3040	PETAINES ALISTENIE	30-0:004	400-01-09	70-5 70 .005"	TRACES OF 100%.	TRACES (.001") OF 100% ON SURFACES	TRACES OF 100% ON SURFACE	TRACES OF 1009	15 70 .002"	30-10 70.005"	100% THACES ON SURFACE, LOOKS	THEFT.	100% TO .0005". 30-1075 .005	LOOKS RETEMP.	47 SURFACE 75, 00225: 50-10	25-10 70.00g	TRACES OF BOR
U	DEPTH (m.)	.019020	.020	.020021	. 02 G	.020022	.020	120.	.018080	6/08/0.	180 - 610.	.018020	.017019	.0/60/8	6/0-9/0.	810910.	610 210.
TRUCTUPES	SITE AND LOWER BAINITE	PREM.	=	2	¥	z	=	*	*	;	÷	2	*	*	*	11	3
エボンの	UPPER BAINITE	30-50	40 - 60 20ARSE	40 - 75 COARSE TO BLOCKY	20-45 610CKY	30-60 004RSE 810CKT	20-35	15-35	15-20	5 MAX.	15-30	TRACES 5%	35-45	7.P.MCES 5.9%	25-35	5-20	15-25
30001W	No.	2-10	3-10	5-10	0/-8	8-18	(A)	3-10	10-15	K 1	2-10	D .	2-10	(a)	5-10	5-12	6-7
رن	2000 B. V.	19-19-19	31.5-34		33-37	30-94	38 -42.5		38-40 335-415	44.5-46	34.5-58.5	44.5-46.5	61.5-35	24-46		49-44	SS-36.5
HARDNESS		13-15	19-10	32-15	B B	32-35	62-12	37-41		46-47	39-44.	45-47.	87-40	46-47	14-04	41-43	52-54 39-41 85-36.5
I		53.5-525	54-56 31-34 31.5-34	•	E10 8 515-52.5	EAQ 3 50.5-52.5 32 - 35 30 - 34	249 8 · 56 - 57 37 - 39 38 - 42.5		CAO.5 55.5.56	54.5-55 46-47 44.5-46	55.5-57.39-44.34.5-38.5	55.5 - 56 45 - 47 44.5 - 46.5	55.5-56.5 67-40 81.5-35	555-55 46-47 44-46		56.5.57 41-45 43-44	52-54
7708	IDENTITY	のでのない	か ひや 可	(A)	(1) (2) (2) (4)	のなって	11) 24:54 12) 12)	B40 4	0405	100 pt 0 p	63.05. 2.05.	A804 40.9	22. 1000 10	400	66118	50,50	22.7. 000

5-20 05-20 06-20 08-20 08-30 0	20-40 .013021 65-5 10.004" [E	5-86 .00.00 01.00.000.000. 810.	3-5 6.15 AFM. 013021 80-10 70.000" THE SMK. 10-20 .017018 55-5 70.008" SE	FERRITE BAINITE BOWTE (IN) AUSTENITE	MICROSTRUCTURES CASE
15-30 018-019 10-15 TO.004 (05.21)	20	.018018 1055 GV .018021 65-5 70.004"	20.01020020020020	2017018020 - 07 - 5 TO .004" 2017018020 5 TO - 07 0 - 810. 2017018021 65 - 5 TO .004" 2018018017 80 - 35 TO .004" 2018 -	STATUTE OF THE SECRETARY AND T
	20 .016017 20 .35 70.025	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	201	2017 0.18 55 - 5 TO . 000 . 25 TO . 000 . 25 . 20 . 000 . 25 . 20 . 000 . 25 . 20 . 20	STATUTE OF THE SECTION SALES SALE

TR	19-1507	GRAIN SQUADEY CONST.	CHE MANNINAM	STATE OF THE WALLET	GENERAL PITTING OVER TO GENERAL PARTY OF THE SHIPPING.	SEE CHIEF OF	CONTRACTOR CONST.	Control of the contro	GRAWY BOWDER CONST. TO GRAWY BOWDER CONST.	FLEET ROUSE IN	CRECTS QUS" N. FILLET	SECTO CONTRACTOR	CHACK CONTRACTOR	Winds die de Contra	CRISCS AL FILLET AND		SK 10 48 5 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	GET TO GOOD PUTTING ON
CASE	ASSESSION OF	TRACES OF JOSE	25-5 70 .004"	"800 OT 08.	60-5 TO .005"	20% 57 50 58 50 50 50 50 50 50 50 50 50 50 50 50 50	(RETENTIONED)	40-10 TO -008	50-10 TO 10 000	50-10 10 .000°	BOUGETENEERS)	45-5 70 .004	10.10 TO .004.	12 15 C.	180 E. CO. S. C. S.		100 00 TO	45.5 70 00%
6	DEPTH (IN INCHES)	610810	810-410	610810.	.022 084	080010	- 088 - OBA	670'-910'	800-210	020810	080610	180	08080	9/0	610:- 810:	8070	810-910	130
URES	SITE AND	REM.	3			*	*		÷	ŧ	3	ì	3	•	•	•		*
h	UPPER	15-35	15-25	5	15-25	0-01	5-10	10-25	25-45	10-25	2-10	15-36	25-65	20.45	2-10	THE SEC TO	25.65	5-70
MICHOSTAUC	THEE UPPER	2-10	10-15	D - 0	5-12	5	20-30	6-5	0/-15	\$5 1	15-25	3-7	ų, S	3-10	5-25	18-30	3-12	9.9
5.5	A Company of the Comp	24-83	39-42	45-46.5	39-41 56-39.5	87-89 885-40.5	3-41.5	38-39 40,5-48,5	37.5-43	35-39 E	30-415	39.5-41.5	36-33	346-39	44	40-48	86.48	42-43 415-435 3-5
HARONESS	CORE LUG	37.00	34-37	45-47 45-46.5	39.41	87-89	39-41 BB-41.5	88.E	33-35 37.5-43	40-4%	40.45	39.41	37.37	39.39	4-48	24-34	36-37	42-43
H	SURFACE	56.58	54-55	56-57	SS85	57-58	80.5	58.5-53.5	53.08.0	28.6-57	585.585	286.285	385-385	52.5-58	57.57	85-45	26-57	26-60
801.7	IDENTITY SURFACE CORE LUG CORE BODY Pe KIN CON RE RE	5.4. Sts	11.ET 402 80016	HRT CKS 56-57	St. Cl. 38-59	男子名 "的家	88/18 18/18	46/18 10/8 10	66.78	8208 84.94	66/18	250	24 05	66/18	87.18	8/1/8	8/1/8	8/139

	REMARKS	SOUTH HEAVY PATTING AN PRILET	SENTE PITTING OFF IN OFFI	PITING.	SIBLE PRICES: PITTING IN	TRINGS OF GBC SCHIE	SO THE ORDER WAS TO SELECT	Series Sans Sancis III	SAMER PITTING BY PULLET PADRICS.	FLEET RIGHTS CHECKING	REPORT SA~TR19-1507
CASE	PENCENT RETAINED AUSTENITE	30-10 10 304"	30-5 10 CON	\$00.00 01-00	20-5 70 .004"	(METERNETERED P)	M. C. T. T. CO.	188 18 000 TE	TENOS OF SOR	45-10 TO .COR	
Ġ	DEPTH (IN INCHES)	910'-910'	610:910	61010	610210	610-410	610:-910	600-910	.083	080-810	
CTURES	SITE AND LONER BAINITE	FEFF		4	;		3		è	•	an isa ka era etter kerasan andra arrenden era era ette kital kiri 1949-1944 (ila 1944 (ila 1944 (ila 1944)))
STRUCT		2-50	2-10	8	TEXCES TO TO	51.6	30	2-10	\$50.46 \$100.46	39.08	
MICHOSTRU	FREE UPPER	1. 10	21-9	9	01-6	0.10	4-6	5-25	9		
20 1		40-4	44.46	455.46	48-46	4.40	42-13	34.48	34.95	64.525 33.34 32.5356 3-7	
HARDNESS	an7 3400	4/-43	171-		40-4	4-4	_	20-57 41-42 34-42	46.325 34.34 34.35	46.69	THE STATE OF STATE PROGRAM AND
H	SURFACE L	28.5.57	50-36.5 48.46	28-24	22.28	25.06	200.000	25.20	216.325	64585	nter i retire ditarim en Poince Moneron municipa differentazione, etc. y aucustratura, que usa que escri
B017	IDENTITY SURFACE COME LING COME BOTH	HAT GAGE	1187 02	147.0405 28.37 41-44	# 187 GOS 55-55 45-4	HRT gos 55.66 41-44	HRT 000 200 56 AF-43	8/10 NO. 4-4	हिंदर हिंदर १२-	1177 A) 1882 7	***************************************

REPORT SA-TR19-1507

APPENDIX A

Section 5

Magnetic and Metallurgical Data on Bolts in Wave Form Pattern Study

REPORT SA-TR19-1507

	REMARKS	L.	E" O HEAVY PITTING ON BOOY WALL AND FROUGE.	E" HEAVY PITTING.	PHTING ON LUG RADIUS AND WALL.	LEW PHINE ON LIE RADIUS AND WOLL		GRAM SELVING CONSTITUENTS TO COOK!	COLORAGE COLORAGE INTERNA		" SEVERE PITTING.		SEVERE PYTING	018-019 WAS TO COLD MENY PITTING CHENCY OF LUG NO PATTURE	16-20% TO COSE HEAVY PHTING IN LUS FRADIUS.	5% TO . COLE" MENYY PITTING, MISSINGH IN LUG AREA.	STATE MICHOLOGICAS COOL MAN, WANDER	1	HENNY PHTING IN LUG WALL AND FRANCE	7 755	THE STATE OF THE S
CASE		AUSTENITE	57 70.00%	10% 10 .00%	TRACES	10% TO . 00E"	10% 10 .002"	TRACES	TRACES	TRACES	15% 70.008"	TRACES	TRACES	10% TO .0015	15-2011 TO .CO	5% 70.00	TRACES	.014-015 10-5% TO.C.	TRACES	15% TO . CORES	018-019 108 10 .001
	DEPTH	(MCHES)	030-610	610:-810:	810-710.	6/0:-8/0	6/0:8/0	9/0-5/0	710-510	610-810	310:-910:	010-80	80-810.	610-810	210-910	015-016	.025-016	.014-015	014.05	.016-018	6/0-8/0
TURE	SITE AND	BANNITE	REM	ŧ	``	`	**	*	2	*	``	*	3	٤	3	````	\	N.	3	8	k
MICROSTRUCTURE	UPPER	BAINITE	5% Park	5-10%	15-25%	5-15%	5-16%	5-8%	5-20%	3-15%	5-10%	5-15%	5-80%	10-50%	5-15%	0-5%	25-0	0.5%	2-8%	5-7%	0-5%
MICRO	FREE	FERRITE	2-17%	3-10%	5-12%	5-20%	5-12%	3-10%	3-10%	5-12%	301-6	5-15%	8-10%	5-15%	5-10%	3-5%	3-7%	5-10%	3-7%	3-10%	9-5%
8027	DENTITY		67988	9/269	77533	78/53	75089	69852	76002	70825	70/90	68722	7/355	73237	60124	70400	18669	74987	74823	77/38	76924

SA-TR19-1507 . '3 10% 70 .00/5" 20% 70 .002" 5% 70 .0015" 5% 70.00/" RETAINED AUSTENITE 45% TO .003" 5% 10 .001 102.07.20 TRACES TRACKS FRACES TRACES TRACES TRACES TRACES TRACKS TRACES **LRACES** TRACES TEACKS! NONE 0-5% 10-5% 70 CASE 018-020 610'-810 0/8-.020 020:-610 010-010 0/6-018 0%-610 018-020 DEPTH (INCHES) 019-020 710-910 020-810 610-810 8/0-2/0 0/5-0/6 015-017 810-210 016-017 020-021 610-910 130-610 0/5-0/7 130-510 MARTENSITE AND LOWER BAINITE PEM. ; > MICROSTRUCTURE 1 1 7 7 * × 2 3 2 3 ** 10 3 " UPPER 5-10% 3-7% 3-7% 0-5% 5-10% 3-8% 2-1% 5-8% 5-15% 5-15% 0-5% 0.3% 3-12% 28-9 3-8% 5-12% 5-122 3-5% 3-8% 3-7% FREE FEARITE 3-10% 3-8% 3-10% 3-8% 3-0% 3-8% 3-5% 3-8% 5-188 5-12% 5-10% 3-7% 3-8% 5-15% 3-8% 3-8% 3-10% 5-10% 3-10% 3-10% 3-8% 3-8% 40.5-42.5 39.5-42.5 345-405 385-45 45-445 43-44.5 43-44.0 39.5-42 41-42.5 455-46 40.5-42 385-42 \$-4.5 42-43 41.5-43 42-44 28-450 \$5-48 395-42 39-42 42-43 44-04 42-43 38-42 S_O 57.5-585 58-595 58-585 58-585 57.5-59 59-59.5 57.5-58 54-56.5 585-59 56-56.5 52-56 57-58 57-58 57-59 28-60 58-60 59-60 57-58 57-58 55.58 53 83 B B MAGNETIC BASIC WAVE FURN PATTER 8 8 8 8 B READING CZ -15 -20 2 8 +22 9. 8 -13 3 9-1. 5 0/-117 5 Q 4 0 DENTITY 72086 72200 76342 72572 70944 74845 75326 72246 69364 63627 75268 69394 69689 58837 70680 70942 69210 69625 69882 66538 70497 69732 BOLT 71153 16169

REPORT

REPORT SA-TR19-1507

APPENDIX A

Section 6

Metallurgical Data on Bolta in Oscillogram Study

REPORT IA-TR19-		REMARKS	HEAVY PITTING.	**************************************	HIGHLY RETEMPERED		CASE IN FILLET . OOP" MAX	GRAIN BOUNDARY CONSTITUENTS			DEEP PITTING.		SEVERELY PITTED.	•	HIGHLY RETEMPERED.					HIGHLY RETEMPERED.	DEEP PITTING.		HIGHLY RETEMPERED.	_	GRAIN GRINDARY CONSTITUENTS	DEEP HAME.
	CORE	RETAINED AUSTENITE	•	5% 70.005		53% 10.002"	5% 10.001"		20.9020 30-25% 10.000	NONE	45.558.TO.002"	TRACES	60-402 10 00g			NONE	NONE	80% 70.002"	TRACES		TRACES		40-30% TO.0025	25% 70.00%	NONE	018-020 40% 70.0085
	<u>()</u>	OEPTH (INCHES)	030-810.	710310.	610-810.	810-910	.017018		05060.	810710.	020-810	610710.	10.7-018	.018-020	130:-810.	050-610	910:-110.	6/0-4/0	810:-710.	810:-210.	810-210.	710-910.		610-910	6/0-4/0	0/8-020
	STURE	MARTENSITE AND LOWER BAINITE	REM	**	*	2	ž	*	*	96	f a	**	e, de	**	\$	**	40	*	**	t	10	2	**	17	*	\$
	POSTAU	UPPER	25-40%	0-3%	30-60%	15-35%	15-40%	3-7%	0-2%	0-5%	0-3%	3-15%	0-3%	0-5%	0-8%	0-5%	0.3%	3-12%	5-10%	0-5%	5-15%	3-12%	10-20%	10-15%	3-7%	2-10%
	10- H	FERRITE	5-10%	0-9%	3-7%	3-5%	3-7%	0-3%	0-3%	0-5%	3-5%	3-8%	3-8%	3-12%	3-12%	8-17%	8-10%	10-177	12-22%	8-20%	8-25%	3-10%	15-25%	10-20%	0-3%	2-10%
		HA PIDNESS Pic	37-39	43-44	35-38	38-39	36-39	42-43	48-45	41-43	42-44	14-04	43-44	42-43	40-42	14-66	41-43	34-37	33-34	38-41	33-35	35-37	29-84	34-97	41-43	35-57
	1709	IDENTITY "	8404 75706	8404 75285	3NO# 84919	SNO4 94678	BACA 177984	AND 72157	403 75794	103 73765	103 74066	15 AOR 57665	403 72127	402 57809	A03 86354	ACS 74623	A03 77797	A23 68008	403 707.57	A03 85147	403 75329	122 74128	403 74384	103 76487	8404 7.2157	A05 94127

A CONTRACTOR OF THE CONTRACTOR												WITCH IN		• بد	^.	~					TR1	rep 9-1	507	C	•
	REMARKS	RETEMPERED.	RETEMPERED		RETEMPERED.	HEAVY PITTING	SEVERITY PLITTED.			HEAVY PITTING		RETEMPERED - MISMATON	HIGHLY RETEMPERED	HIGHLY RETEMPERED	HIGHLY PETEMPERED	HIGHLY RETEMPERED	HIGHLY RETEMPERED	HIGHLY RETEMPERED	HIGHLY PETEMPERED	HIGHLY RETEMPERED	HIGHLY RETEMPERED	HIGHLY PETEMPERED.	HIGHLY RETEMPERED	CHERITA DETERMENT	The state of the s
CORE	RETAINED AUSTENITE	TRACES	TRACES	NONE	TRACES	50-40% TO .005	.018019 25-10% TO age	TRACES	TRACES	40-30% TO. 005	40.50% TO 0000°	TEMOES	TRACES	gangunan - A											
Ö	DEPTH (MCHES)	810710.	810210.	6/0-8/0	020-021	810-810	610-810	0/4-0/6	810:-810:		610-810.	020-810.	.015016	080-810	610:-810.	5/0:-8/0:	016018	020-810.	017-018	.OT-0/8	.017-018	020-90	710-910	610-810	· · · · · · · · · · · · · · · · · · ·
STURE	MARTENSITE AND LOWER BANNIE	REM.	,,	*	"	ħ	×	ъ	Ä	ij	11	¥	'n	"	"	#	×	"	u	*	"	*	<i>y</i>	¥	
MICROSTRUCTURE	3UNIVB 33CHI	12-22%	7-15%	3-8%	0-5%	0-5%	5-8%	5-10%	3-15%	5-12%	10-20%	3-5%	3-8%	20-04	35-55%	15-25%	3-5%	60-75%	3-5%	3-7%	10-15%	2/-0	40-60%	35-75%	
	FREE	12-22%	17-25%	2-11-2	3-10%	3-10%	3-5%	12-22%	3-7%	2-12%	251-1	3-5%	3-2%	5-8%	5-8%	0-5%	0-3%	3-7%	3-5%	3-7%	2-10%	0-1%	8-10%	5-15%	
CORE	HARDNESS Re	33-34	34-36	14-04	41-43	41-43	42-43	3435	38-40	88-38	84-35	41-43	42-43	31-34	33-34	35-37	24-14	34-35	40-42	37-39	37-39	46-47	34-38	经多多	
BQZ.T.	IDENTITY	A03 67282	A03 76750	A05 78204	A03 84563	AO2 72050	402 65518	A03 75854	403 C	A03 71362	. A03 68763	A03 87339	A05 86750	BAGS 84596	BAOS C-6	Brich 302	Brow CB	BACS 86920	B404 7-2	BACS 86406	8408 77238	BAC4 7-1	6.400 849AB	BADS 84967	

report Sa-tr19-		REMARKS 3		OVERHEATED IN GRINDING BOOK	GRAIN BRUNDARY CONSTITUENTS	HEAVY PITING	RETEMPERED.	HEAVY PITTING IN BOOK WALL.	35-25\$ TO. COS" HEAVY FITTING.	OVERHEATED IN PADUS AND BACK.	OF LUIS TO A DEPTH OF SOF. GOS.	DEEP PITS.	TRANSFORMED IN GRINDING OR	TRANSPORMED IN GRINDING OR	TRANSFORMED IN GRINDING OR	CUITING OFF.		MODERATE TO HEAVY PITTING.	-	HIGHLY TEMPERED.		DEED PITS - HIGHLY TELYPERED.	HEAVY PITTING.	GRAIN BOUNDARY CONSTITUENTS	PETEMPERED.	RETEMPERED
	CASE	RETAINED AUSTENITE	NOWE	TRACES	5% 10.001"	TRACES	15% 10.0015"	30.20% 70.005	55-25\$ 70.005	45-35% TO 002"	TRACES TO 5%	TRACE				15-10% 70.008			,	10-5% 70.005	TRACES	5% 70.003	AONE	NONE	NONE	NONE
	S	OEPTH (INCHES)	310-410	050-610	810-210	.018020	020-810	080-810	120-610	6/0-2/0	.077-019	080-810.	018-020	710-910	810-710	710-310.	610810.	80-410.	020-810.	810-410	.020-022	610-810	030-810.	610-810	810-710.	710-910
	CTURE	MARTENSITE ANS LOWER BAINITE	REM.	``	``	``	``	ł	``	*	ï	*	,	u	*	0	***	ħ	,,	//	*	1	t	и	3	*
	MICROSTRUCTURE	JAPER BAINITE	2-2%	5-10%	3-5%	5-15%	3-8%	3-8%	5-20%	2-10%	2-15%	10-50%	2-10%	201-5	2-15%	2-10%	0-5%	0-5%	0-5%	5-15%	5-15%	2-10%	10-50%	15-20%	0-3%	2-15%
	MICH	FREE	3-7%	3-10%	3-12%	10-22%	5-10%	5-12%	10-22%	12-25%	10-22%	5-20%	2-15%	5-17%	10-222	2-10%	2-10%	15-25%	3-8%	202-01	7-15%	7-35%	5-15%	10-20%	8-10%	2-17%
	3200	MATTONESS Pre	41-43	39-42	41-42	36-38	39-4/	38-39	32-35	34-37	32-34	34-36	37-41	37-41	33-37	40-43	38-42	38-38	41-44	32-34	37-38	32-33	87-39	34-37	42-44	39-40
	D077	DENTITY	ACS 77071	403 75061	AO2 65722	402 69039	403 13620	103 72876	403 81179	403 69689	A03 76/38	403 74516	307 07 20K 25	19659 804	403 70085	AO2 71557	A03 70713	A03 66772	A02 71117	11099 80%	AO2 77643	A03 76416	19311 208	16012 5031	403 76273	A02 7464

Section 7

Impact and Metallurgical Data on Bolts on Impact Test Study

T 19-1	\$07			*	wiping or an a	***************************************	man se de de deservir				Ar 24.00	Addings to a process	try water rose w	B •	one-rectang existe nt	,	dissersitivitari	, c	Ogresia i	er our expression		b.				CERUTA-
CASE	RETAINED AUSTENITE	10% 70 .003".	TRACES 70 59%	5% 70 .002"	5% 70 .003"	10% 07 60%	TRACES	NONE	TRACES	TRACE	TRACES	TRACES	TRACE	10-5% 70.002"	5% 70.002".	15-10% 70,002"	TRACE	10-5% 70.00%	10% 10.0015	NONE	NOWE	10-52 10.005	NONE	7784225	NONE	(PROEUTSETOVO CE
	DEPTH (INCHES)	610-210	120-6/0	0/8-020	710-910	020-021	020-021	810-210	.0/50/6	.020-022	610-210	710-510	120-610	610-210	610-810	610810.	810:-210	710910.	.016-017	018-020	080-080	210-710.	210-210	0/5-0/6		
TURE	MARTENSITE AND LOWER BAINITE	REM.	//	77	***	***	7	4	*	15	,,	***************************************	*	*	"	*	#	18	¥.	8	8	7	\$	9	1	- Star Lyweg v
STAUC	STINIAE RAINITE	3-5%	3-8%	3% MAK.	5-12%	5-10%	5-20%	3-5%	8-12%	5-15%	5-15%	10-20%	12-22%	3-5%	3-7%	5-15%	15-20%	3-7%	3-12%	10-20%	5-20%	5-15%	15-35%	8-12%	1520%	1000
MICRO	FERRITE	3-8%	2-8%	3% MAX.	3-10%	3-8%	5-12%	3-5%	10-20%	7-15%	5-15%	2-15%	5-15%	3-5%	3-7%	10-25%	15-20%	3-7%	3-12%	5-15%	5.20%	8-20%	2-15%	10-20%	10-20%	
NESS	ADJACENT LUG CORE	44-45	名-分	43-45	84-14	41-42	42-43	45-46	14-95	39-40	39-40	37-38	38.40	44-45	F.	39-40	88-83	40-44	41-43	74-14	38-33	2	28-89		35-38	40-41
HARDI	SURFACE Pe	56.5-33.5	56.5-58.5	55-59	27-60	57.5	585-59.6	558	58-59	59	56-58	55.5-58	SE-59.5	56-58.5	57-59.5	55.5-57	56.5-575	51.585	58-59	28-57	56-57.5	57:59	555-585	53-555	58.5-60.5	57,50
	HA!! CHN	Ŋ	Ŋ	Ø	ß	`	Q	Ŋ	8	4	Q	\	S	Ŋ	W	2 FERRITE	2 FEPRITE	W	Q.	N	2 FERRITE	2 FERRITE	2 FEARITE	2 FEARITE	2 FERRITE	O EL POTTE
MENETIC	READING	-/2	-17	0	-/5	-A0	-11,	- 7	9	//-	-23	8	-12	0/-	7/-	-25	-22	2-12	00	-13	24-	-53	-A-	2/2	į,	Įç I
SUCHES TO	SOLE NT.	`	\		`	\	ત્ર	8	Q	Q	Ø	Ø	3 MC	4	A	6 INC.	6/NC.	9	9	9	10 INC.	>	12 INC.	4	\$ 12.	20 100
BOLT	DENTITY	402 6,9497	403 73843	403 7654	102 7445B	103 RESES	402 67448	403 GEFTE	402 69418	AO2 77643	. 402 6702/	403 75033	A03 15	409 11632	ACE 67254	103 75885	403 70085	A02 71116	402 69083	402 71381	403 75852	402 68725	103 66772	403 6948!	403 71091	403 76993

Section 8

Impact and Metallurgical Data on Tempered Bolts in Impact Test Study REPORT SA-TR19-1507

CASE	PRETONNED ALKETENITE	5% 70.002°	5% 70 .002".	15-10% 70.008"	TRACES.	NOME	NONE	NOWE	NOWE	10% 70.003".	10-5% 70.002".	5% 70.002"	TRACES	NONE	NON	NONE	3NOW	ZWOW.	NONE	MONE	NONE
	OEPTH (INCHES)	.018020	0/0-8/0	018-020	.020-022	6/0:010	014-016	8/0-2/0	6/0:	023-024	9/0-2/0	810-210	0/6-0/8	.0/20/3	.020-021	0/3-0/5	014-015	810-710	710-910	410-210	013-015
CTURE	MARTENSITE AND LOWER BAINITE	REM	ĭ	٦	13	₽	*8	B	"	Ŋ	B Y	"	u	B	ga	11	Ħ	¥	ঝ	Ħ	"
	UPPER	5-15%	3-8%	5-7%	0-5%	2-10%	0-5%	3-5%	5-10%	3-10%	3-5%	5-15%	0-10%	10-15%	2-10%	5-15%	10-15%	3-5%	3-6%	10-12%	10-20%
をごろ	FERRITE	5-17%	3-8%	5-7%	3-5%	5-12%	3-78	3-5%	5-10%	5-10%	3-5%	7-10%	3-7%	10-20%	3-7%	5-15%	15-25%	3-5%	3-10%	10-22%	10-20%
VESS	COPE LUS	38-40	41-43	84-14	44-45	24-14	42-43	43-44	4-42	40-42	42-43	25-04 05-04	39.4	38-33	\$ - 6%	35-39	36-38	42-48	40-42	39-4/	36.5-39
HARDNESS	SURFACE Re	55-57	57-58	57.38	56-57.5	58.5-59.5	53.54	28-57	585-5B	58-585	58-59	58-57.5	25-59	46-49	53-555	49-50	50-51	8-8	57.5-53	52-55	49-51
ALCINS TO FUPTURE	30 FT 185 / 820W 2018 HAYMER	_	_	_	_	_	_	_	Q	2	Ŋ	4	60	Ø	9	41	20	22	35	82	83
ALCINS TO PUPTURE	FA / / EKW	10	\-\ <u>\</u>	<i>/-2</i>	\-\-\-	1-0	9-1	/ C	1-0	/-0	1-0	/-Q	B-/	A-/	8-1	7-4	7-4	1-8	1/8	A-/	1-4
307.7	DENTITY	14448	85359	86053	78759	84749	83597	7660/	88/26	19068	88870	85/38	01198	86596	89/65	86404	86307	李的	84668	35438	36000

APPENDIX A

Section 9

Impact and Metallurgical Data on Bolts in Impact Cold Test Study REPORT SA-TR19-1507

-	1														8	>	
CASE	RETAINED AUSTENITE	TRACES	TRACES	TRACES	TRACES	TRACES	NONE	TRACES	NONE	TRACES	TRACES	NONE	NONE	TRACES	50-25% 70.005"	40-30% 70.002"	NONE
•	DEPTH (INCHES)	.020021	910-210	.015016	.018020	6/0-8/0	5/0'-8/0'	.018020	810'-210'	.019021	2/0-9/0	710-910	610:-210.	610810.	610-210.	6/0-8/0	.019020
TURE	MARTENSITE AND LOWER BAINITE	REM.	"	*	**	*	*	*	ĸ	`		*	15	•	łą	*	*
MICROSTRUCTURE	UPPER BAINITE	0-5%	3-5%	65-75%	3-5%	15-25%	3-8%	190 MAX.	0-3%	0-5%	40-60%	5-15%	26-0	3-10%	3-8%	3-5%	0-5%
MICA	FERRITE	3-10%	3-5%	8-12%	3-5%	0-5%	201-1	190 MAX.	8-10%	2-2-8	8-10%	5-17%	8-127	5-12%	3-8%	5-5%	8-17%
	MARCINESS	41-44	4-42	35-36	41-435	33-87	425-44	45.5-47	45-45	41.5-44	34-36	36-38	41-42	37-40	14-04	41-42	39-41
	MARLAVESS	56-58	56-57	52-555	56.5-57	58-57.5	ST-33	54-58	56.5-57.5	56.5-59.5	55.5-57		57-58	58-59	57.5-585	57-585	58.5 085
HE/GHT	(WCHES) ARCHESS	4	15	B	15	14	1/2	8/	ó	Ø	8)	9	6	6,	80	B	8
BOLT	DENTITY	84563	8404 F2	BA03 C-2	87339	8404 302	18204	12 2008	76273	73200	84948	74664	16414	403 304	402 308	403 810	74623

	REPORT 17:1507	
-	rr19-1507	

		** 100 m ***	10 to 40 II			70 SL 60 60	(B E) 10 db											
CASE	RETAINED AUSTENITE	5% 70.002"	10% 70 .002"		TRACES	TRACES	TRACES	TRACES	TRACES	TRACES	TRACES	50-20% 70.002"		NONE	TRACES	TRACES		SA
	DEPTH (INCHES)	.0/8020	.0/70/8	.018020	810910.	.018020	610810.	810-810	.017018	610-810.	610-810	6/04/0.	810-710.	.017018	810210	610-210.	810210	
TURE	MARTENSITE AND LOWER BAINITE	REM.	*		8		ì	`	#	*	*	8	*	*	3	k	28	
0	UPPER BAINITE	3-5%	3-7%	5-5%	3-10%	3-10%	3-7%	3-15%	5-15%	26-0	3-5%	5-10%	25-8	0-3%	5-10%	3-12%	0-5%	
MICH	FREE FERRITE	2-10%	32-22	3-5%	10-22%	10-17%	10-15%	3-7%	8-25%	0-3%	5-17%	2641-01	5-5%	3-8%	12-22%	10-17%	8-20%	
100 core	HAROWESS Re	41-43	43-45	47-44	33-37	35-37	36-39	38-40	35-33	44-24	25-39	55-39	£9-42	43-44	52-34	£3-37	38-41	
		57-575	47-485	56-53.5	565-575	525-545	56-575	54.5-57	55.5-57	535-60.5	55.5-57.5	565-585	565-58	19-5:09	56-575			
HEIGHT	IDENTITY (WENES) REPORTED	2/	13	18	12	22	22	23	23	23	25	25	25	25	30	B	94	
2708	DENTITY	A03 306	A23 307	A05 509	A03 F-3	ACC F-2	103 F-5	103 C-1	75329	81559	102 301	403 503	A03 C-4	72127	70757	80089	85147	

LOCAL PROPERTY OF THE PARTY OF

Sales Page His 1975 VIII

DISTRIBUTION

	Copies
Chief of Ordnance	3
Department of the Army	3
ATTN: ORDTB (1)	
ORDIX (1)	
ORDIR (1)	
Washington 25, D. C.	
Commanding General	1 #
Ordnance Weapons Command	15
ATTN: ORDOW-FM (1)	
ORDOW-TX (1)	
ORDOW-IE (1)	
ORDOW-IA (5)	
ORDOW-IX (1)	
ORDOW-IM (5)	
ORDOW-GN (1)	
Rock Island, Illinois	
Commanding Officer	2
Diamond Ordnance Fuze Laboratories	4
ATTN: Technical Reference Section	
ORDTL 06.33 (1)	
ORDTL 012 (1)	
Washington 25, D. C.	
Armed Services Technical Information Agency	10
Arlington Hall Station	10
Arlington 12, Virginia	
Commanding General	4
Aberdeen Proving Ground	7
ATTN: Technical Library, ORDEG-LM, Bldg 313 (2)	
DPS, Branch Library #3, Bldg 400 (2)	
Aberdeen, Maryland	

DISTRIBUTION - Continued

	Copies
Commanding Officer	1
Cleveland Ordnance District	
Lincoln Building	
1367 East 6th Street	
Cleveland 14, Ohio	
Commanding Officer	1
Boston Ordnance District	
Boston Army Base	
Boston 10, Mass.	

One each copy of this report is forwarded to ORDOW-IM for transmittal to Thompson Ramo Wooldridge, Harrington & Richardson, and Olin Mathieson companies. Since the report is coded, the Code Identification Sheet has been removed from these three copies of the report as required by paragraph 5b(4) of OCTI 200-9-61:

Commanding General
Ordnance Weapons Command
ATTN: ORDOW-IM
Rock Island, Illinois

APPENDIX B

3

2. holt, min, ".a.m.
3. fleetremagnette
to the widele welked was found to be the overplacated to appetly as a final or improves a laspecular orgensation to sit, (a) situitated impact teats, and (3) application to that and twreagram comid by most as a moone to determine uniformity of compensate within itsiby L. B. Horystones, R. P. metth, mas is, n. Alber, Trets uper Ma-Thibu 1307, 4 jam 62, process tapperlim. A peri mind tabbinag battail C mefad battain, apperlie processility products, and metition my may long patterns and developed to realiz-PROPERTIES AND PETRODES OF HONOLITHECT PLETTING OF BOLES FOR 7.4 DEP HIS REPLEE, dendine were made to develop adequate inappetines welkade of evaluating properties method, a magnetic comparison method similar to that orplayed in the negropation is stain and medical presentability comparisons, unabersonate of basic angrette propersional host lats. Procedures are discound and frontic given. It uss recommended the leasibility of work, the developed sethed for flust and improcess imprection CICLASSINID REPORT These studies included (1) investigation of boil malfunction, (2) numberthuretive ties, sutilizatope upon fore pottore studies, bardones lorestigations, (3) balt to ye inel tables and tiles, 199, Proj fittle bundentrutten ftating, 32 Cade ate properties of anteriol and in the laber wie beit. The combination took of embettal mend to the Industrial of the I.albe Fit bolts, and to determine 4010.77,8007.4.81, Insectial Production Incimoring Project. Apringfield Advant, Springfield, Pade.

2. with 784, 7.62m), Electromagnetic Last methods method one formed to be two complicated to opecify as a final or in-pressue imaportion organyation 'sots, (4) similabed impact Truts, and (3) opplication to finel and inprogres sends be used as a master to determine welforestry of empression of this ladi-PROPERTIES AND PETITODS OF HONOGENICETY TESTING OF BOLES FOR 7.4-RP HIS ESPEES, by h. h. merytaechi, n. 7. metch, and f. n. abon, Tech Spt Ep-7219-1307, a Jan 63, presson famportian. A test without combining Bactuall C carface hardwood, capabile andillity resultage, and seciliarsape were fate potterns was developed to evalue mithed. A segmette emperious wothed stellar to that employed in the expression Studios was made to devalop adequate impaction without of evaluating properties the foachility of noing the developed nothed for final and improves imspection. wote or engantic perceptiity ampations, menorumnis of beat magnatic proper-UNCLASSIFIED REPORT Then states tembeted (1) tensetigation of belt mathematica, (2) unadestructive tion, estillestupy were form pottern studios, bardanos investigations, (3) bolt on properties of meerical used to the 2.63m with balt. The numbination bear sident but both. Franchist or discussed on results given. It is recom-M cy imi tobies and illes, IM, Prej fitte Bunbetretter hating, Old Conof meering and to the fabrication of the 7,53m bit bein, and to describe MIG.Z3.0003,4.81, Industrial Production Ingineering Project. The state of the section of Springfield Arrusy, Springfiels, Pass.

Appropriate Armany, Springfield, 7000.	
PROFESTIES AND WITHOUS OF MANDESPRECTIVE TESTING OF MOLES FOR 7,620% HIS RIPLES.	
	De section
96 pp lanel tombies and allane, 199, Prej 31the Numbentructive Seating, Ord Come.	Palt, Mi4, 7.62m
4010,35,0005,4,01, Industrial Prediction Ingineering Project,	Lloctronguetle
Studies were made to develop adequate longerties authors of evoluting properties	Precesses and precessing
of emittrical moored in the Embricactions of the J. bluer Fit besite, send to determine	
the fencibility of maing the developed method for fine) and improcess imprecises,	
These studies trainmed (1) issuestigation of bult melfonction, (2) someournective	
tents we separate provediting comparisons, meanwheats of boole segment proper-	
ties, escillementer were fore paterry studies, bardames investigations, (3) belt	
Degregation train, (4) simulated impact train, and (3) application to final and in-	
presse impuction. A test method cambining hocomell C surface hardway, magnetic	
permeability tradings, and excilionatops wave fatte patterine was developed to evalu-	
ate presenting of enterial used to the Jahler pile bolt. The combination test	
reclined was found to be two complicated to specify me a finel or improcess inspection	
wethod, A ungmetic comparison nothed similar to that suplayed in the segregation	
program could be used as a under to determine amilierally of components within this-	
videal heat loca. Freezederss are distracted and recoilts giurn. It use trecommunded	
land the lower series program to confidence.	

2. Bell, N14, 7, 62m 3. Electronagaetic test authods PROMETRY AND PROMES OF AUGUSTRATING THE TATABLE OF BOATS FOR J. NOT WITH THE TATABLE OF BOATS FOR J. AND PROMES OF AUGUSTRALITY OF SALES AND THE TATABLE OF BOATS FOR J. AND T. AND T rethod was found to be ton complicated to epocity as a final or in-process laspection mproposion trees, (c) numbered espect trees, and (C) application to final and to-propose inspection. A tree united combining becoming contract markets, majorite by M. B. Larytonas, M. P. Hotch, and E. H. Abber, Treh Mpt 54-7819-1507, 4 Jan 52, progress could be used as a means to determine andigenalty of companeeds within land. Stadies were made to develop adequate inspection methods of evaluating properties the feasibility of maing the developed rethod for fine) and im-process inspection. ivata se separate pereability comparisons, measurements of basic maperite proper-tive, escillancings ware form pottern andies, hardware investigation, (3) balt perweshility tradings, and sociliancape wave farm patterns was druelayed to craissethed. A expetit comparison wethed similar to that orphyrd to the organism These studies included (1) investigation of belt relianction, (2) numbertructive DICLASSINIES UPPRI aty properties of waterial used in the 7.52m wit beit. The combination test M 99 incl tabirs and illus, IPs, Proj Title Tundestructive Testing, Ord Code of material wased in the fabrication of the Judger Filt builts, and to determine vidual heet lots. Procedures are discussed and requits given. It was recomm 4016.23,0009,4,01, Industrial Production "mgimerting Project. "Permitted in making in the comment of the Springfield arreit, Springfield, Pana.

L. balt, Hit, J. than 3. Clercrossymile to the methods to Processes and processes, NOTIFIES AND ACTION. > CONCENTRAL TESTING OF NOLTH PR. 1. ADDR NIN SITUAL. 1, NOMBRETTHESING. NOTIFIES AND ACTION > CONCENTRALING. retined with found to be ton camplicated to specify he a final or inspraces inappetion withd. A separate comparison until statute to that employed to the undergrades. by R. A. Envytones, R. P. Morceb, and E. R. abbe, Took Hot 34-72(5-1307, a just 42, ties, metillestaps was for priors evolve, becames immitigations, (1) ball mystelian veit, (4) cincled types (1014, and (5) application to that and prodeadies were made to downlop adoptate laspection methods of evaluating properties the feesibility of usin, the developes rethet for final and improves importing. Then states technical (1) towardigation of butt malbaction, (3) annihological to fine the state of the state process imagestion. A test method conditing Ameliand C surface hardway, suggestion permeability readings, and cacilidatops were for patterns was developed to evalue stand hast lots. Precedures are discussed and traults given. It was trepumped DACLASSIVIZO REPORT ate properties of material ward in the Jaker pla balt. The combination tool M po inel tobles and Illus, 199, Proj ficie Pundentruetim frattug, des Cade of meletical used to the labitication of the Pasher six builts, and to despresses 4010.73.0005.4.01, lumucrial Production Inclusive Project Springfield arrest, "pringfield, buss.

2. wit, nis, 2.62 PARTITLE AS PETICES OF CONCESSION TESTING OF BOATS FOR 3.450m ain 11/124, 1, memberseller method was famed to be ton complicated to appetly on a final or improcesse improclim by R. B. Sarrycannic, R. P. Hotch, and E. S. Abber, Tech Rpt Sh-1919-1901, 4 Jan 62, tion, metilimensy more fore parters creditor, harbons temetigations, (3) built mappagains totis, (4) simulated impact botts, and (5) spplianties to final and im-presses languation. A toti method emailing beamed (outless becames, mappatic incided, a separate comparison method statists to that employed in the empropertaments which we can be a common to determine and formerly of companies within table to the terminal base late. It was presumented for translate plane. It was presumented to Shuddon were made to develop adequate inspection wethods of evaluating properties permeability readings, — excilisecope wer fore poterns was developed to emisthe fossibility of waing the developed setted for flash and im-pressus importion. trots ty magnetic permeability comparisons, measurements of basic magnetic proper-These studies included (1) towastigation of bolt maifumeties, (2) weathestive INCLASSING REPORT to po lesel tabine and illine, IPt, Proj firtie bendenervertier feating, Gid Conte ste properties of material and in the John Hit beit. The combination but of sectorial mand in the Cabrication .. the Jabbe Wik bolts, and to determine 4010.25.0005.4.01, Industrial Production Definioring Project. the terretained program to continue Springfield Arresty, Springfield, Posts.

	FLES. 1. Bandontructive	2. Pate, 814, 7.43	3. Electromagnetic	i	erries protessing		# (C)	- Lames	112	1	agmetic	-alla-	•	lacpic files	en 730 l	in leafs.	
Acresin Seringis id arms?, Springis id, heas.	MORTHILL AND WINDOS OF MONDERHALTHY TEXTING OF BALLY ARE 7.420% HIS TIPLES, by K. By, Espytemal, R. P. March, and R. R. Adde, 1945 has destructed at the area	of py fact rables and allas, 194, Proj Ittle tundentructive Teating, Ord Cade	4010.23,0025,4,01, Industrial Pendectius Engineering Project,	UNCLASSIFIC REPORT	Studies were made to describe adoquate imagentium methods of emblusting properties	the freehbility of main; the developed sethed for final mag inspractual immersion	There studies included (1) Laboratigation of built malfunction, (2) mandestructive	trats to respect to perventility comparisons, measurements of banic emprets proper-	tivs, secilisacope wave fare patters stadies, hardmas ideastigstions, (3) belt	mgregation trets, (4) nimblated impact trats, and (3) application to Elast and in-	process inappaction. A test untiled combining Decised! C surface hardense, enguetic	permeability tradings, and eaciliescape nave fate perceins was developed to evalu-	ate properties of untertial used in the 7. phr bit, the combination test	weiched when fowend so he the complicated to specify no a final or im-process lampication	sethed. A expectiv comparison method similar to low orplayed in the segrepation	program cruid be used as a sease to dotarpise uniformity of consensate utthin Indi-	vidual that lots. Freesdores are discussed and traults given, it was recommended

Springfield Armery, Springfield, Paus.	
MUNICATICA AND RETICOS OF AUDICATICATES TEATING OF RELIS AND 7,620°F MIN MITLES, 1, No.	Pende at the t I wa
	Intract
M 34 inc. tobles and titus, 179, froj fittle "undratructive Tratiet, 3rd gade 2, to	Self, Nis, 1.52m
4810.23.0005,4.51, Industrial Production "majmerring Braject,	Electroragnetic
מיכות בייות שייבות הייות	Prescables and
Standing were made to develop adriguets inspection methods of evaluating properties	prace and the
of material wast in the fabrication of the Luber rit boits, and to determine	
the feasibility of maing the developed rething for final and im-process saspection.	
These studies included (1) investigation of built reliamation, (2) numberthative	
teats to regimetic permutability competions, unknowness of basic magnetic proper-	
ties, entitlescope were form pattern armites, barthess tweestigations, (3) balt	
segregation tests, (4) atrulated impact tests, and (3) application to final and ta-	
process inspection. A tret method cambining beckenil C ourlace betdeen, magnetic	
primenbility readings, and macilloacops were form patterns was developed to engin-	
ate properties of amtreial used in the J. alex 914 bolt. The combination test	
rethed was found to be ton complicated to specify as a final or impreces imagetion	
method. A magnetic comparison method similar to that orployed in the segregation	
program could be used as a means to determine well-loyally of companies elithic lact-	
vidual bont lots. Freeedarus any discussed and results given. It was recommydes	
A 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	